

Draft Engineering Evaluation And Cost Analysis

Omega Chemical Superfund Site
Whittier, California

April 29, 2005

Prepared for:

Omega Chemical Site
PRP Organized Group

Prepared by:

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April 29, 2005

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Subject: Submittal of Draft EE/CA Report
Omega Chemical Superfund Site
CDM Project No. 10500-37240-T1.GW.EECA
CDM File No. 10500-5.2.3

Dear Mr. Lichens:

On behalf of the Omega Chemical Site PRP Organized Group (OPOG), Camp Dresser & McKee Inc. (CDM) is herein submitting two copies of the Draft Engineering Evaluation and Cost Analysis Report. Copies of the document have also been transmitted to the individuals indicated below.

Please feel free to contact me (949/930-2941) or Chuck McLaughlin (951/222-0387) if you have any questions.

Sincerely,

CAMP DRESSER & MCKEE INC.

Sharon L. Wallin, R.G.
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Enclosure

cc: Tom Perina, CH2MHill (2 copies)
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Executive Summary

Executive Summary

The overall purpose of this Engineering Evaluation/Cost Analysis (EE/CA) is to provide a framework for, and documentation of, the evaluation and selection of removal action alternatives that pertain to groundwater contamination on the Omega Chemical Phase 1a Area (Site). The removal actions considered in this document are only one component of the overall remedy that will address contamination associated with the Site. Other components will include remedies that will address on-Site soils.

An EE/CA is similar to a focused feasibility study, in that it provides summary information about the nature and extent of contamination and the related risks and then evaluates alternatives aimed at removing site contamination and reducing the associated risks. Since the scope of this evaluation covers only groundwater, the removal actions that have been selected for evaluation were chosen mainly because they provide containment migration control and remove contaminant mass from groundwater associated with the Omega Site. The selected removal action alternatives are all evaluated, with no initial screening of alternatives as is typically done for a feasibility study, and in this sense the EE/CA is more streamlined than a feasibility study.

The specific Remedial Action Objectives (RAOs) for this EE/CA are:

1. Provide horizontal and vertical containment within the Phase 1a Area of groundwater contamination associated with the Omega property.
2. Meet air emission and water treatment standards associated with the treatment and/or reuse of extracted groundwater.

Three removal action alternatives have been defined and evaluated in this report:

Alternative 1: Source Area Contaminant Mass Removal from Groundwater

This alternative provides for 14 groundwater extraction wells in the suspected source area where contaminant concentrations are the highest to maximize removal of contaminant mass. A treatment system on or adjacent to the Omega Site would treat extracted groundwater which would then be discharged to surface water/storm drain or sanitary sewer.

Alternative 2: Source Area Hydraulic Containment for Groundwater

This alternative includes five groundwater extraction wells along Putnam Street. Pumping from these wells would contain the plume and prevent further migration of contaminants beyond Putnam Street. Extracted groundwater would be treated by a treatment system located on or adjacent to the Omega Site. After treatment, extracted groundwater would be discharged to surface water/storm drain or sanitary sewer.

Alternative 3: Source Area Hydraulic Containment for Groundwater with Re-injection for Enhanced Anaerobic Biodegradation

This alternative is similar to Alternative 2, with the exception that treated groundwater would be mixed with amendments and re-injected in the source area to stimulate enhanced anaerobic biodegradation (EAB) and expedite the removal of groundwater contaminants in the source area.

Compared to Alternative 1, Alternatives 2 and 3 have significantly higher ratings for reduction of contaminant mobility and overall protection of human health and the environment due to their ability to provide superior contaminant migration control downgradient of the Site. Additionally, Alternative 3 provides greater contaminant mass destruction via treatment when compared to Alternatives 1 and 2.

Although contaminant mass removal is not a RAO, Alternative 3 offers additional benefits by reducing contaminant mass up gradient of the containment system. Alternative 3 rates lower for some other evaluation criteria (e.g., higher cost and lower short term effectiveness due to risks associated with construction) because of implementation issues regarding re-injection of treated groundwater for EAB. However, the additional efforts and cost associated with this aspect of Alternative 3 are justified by the additional benefits it provides. This is the basis for selecting Alternative 3 as the recommended alternative.

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List of Acronyms

ALs - Action Levels

AOP - advanced oxidation process

ARARs - Applicable or Relevant and Appropriate Requirements

ASTM – American Society of Testing Materials

bgs - below ground surface

BMPs - best management practices

CAA - Clean Air Act

CALs - California Action Levels

CCR - California Code of Regulations

CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act

CFM – chloroform

cis-1,2-DCE - cis-1,2-dichloroethene

COPC - contaminants of potential concern

CSDLAC - County Sanitation Districts of Los Angeles County

CTC - carbon tetrachloride

CWA - Clean Water Act

1,1-DCA – 1,1-dichloroethane

1,1-DCE – 1,1-dichloroethene

DNAPL - dense non-aqueous phase liquid

DWELs - Drinking Water Exposure Limits

EAB - enhanced anaerobic biodegradation

EE/CA – Engineering Evaluation/Cost Analysis

H&SC – Health and Safety Code

HEAs - Health Effects Advisories

hp – horsepower

HSWA - Hazardous and Solid Waste Amendments of 1984

MC - methylene chloride

MCL - maximum contaminant level

MCLGs - Maximum Contaminant Level Goals

MCLs - Maximum Contaminant Levels

mg/L - milligrams per liter

MSL - mean sea level

MTBE - methyl tertiary butyl ether

NELCO - New England Lead Burning Company

NHPA - National Historic Preservation Act

NPDES - National Pollutant Discharge Elimination System

OEHHA - Office of Environmental Health Hazard Assessment

OPOG – Omega Chemical Site PRP Organized Group

1,1,1,2-PCA – 1,1,1,2-tetrachloroethane

PCE – tetrachloroethene

PHGs - Public Health Goals

POTWs - publicly-owned treatment works

PZ – piezometer

RAOs - Remedial Action Objectives

RCRA - Resource Conservation and Recovery Act

RWQCB - Regional Water Quality Control Board

SCAQMD - South Coast Air Quality Management District

SDWA - Safe Drinking Water Act

SRE - streamlined risk evaluation

SVOCs - semi-volatile organic compounds

SWRCB - State Water Resources Control Board

T-BACT - best available control technology for toxics

TBCs - to be considered

1,1,1-TCA – 1,1,1-trichloroethane

TCE – trichloroethene

TDS – total dissolved solids

TEAP - terminal electron acceptor process

TS - treatability study

TSDFs - Treatment, Storage, and Disposal Facilities

ug/L – micrograms per liter

USEPA – United States Environmental Protection Agency

UST - underground storage tank

VC - vinyl chloride

VOCs – volatile organic compounds

WDR - Waste Discharge Requirements

WRR - Water Reclamation Requirements

Section 1

Section One

Section 1

Introduction

1.1 Scope and Objectives

The overall purpose of this Engineering Evaluation/Cost Analysis (EE/CA) is to provide a framework for, and documentation of, the evaluation and selection of removal action alternatives that pertain to groundwater contamination on the Omega Chemical Phase 1a Area (Site). The removal actions considered in this document are only one component of the overall remedy that will address contamination associated with the Site. Other components will include remedies that will address on-Site soils.

An EE/CA is similar to a focused feasibility study, in that it provides summary information about the nature and extent of contamination and the related risks and then evaluates alternatives aimed at removing site contamination and reducing the associated risks. Since the scope of this evaluation covers only groundwater, the removal actions that have been selected for evaluation were chosen mainly because they provide containment migration control and remove contaminant mass from groundwater associated with the Omega Site. The selected removal action alternatives are all evaluated, with no initial screening of alternatives as is typically done for a feasibility study, and in this sense the EE/CA is more streamlined than a feasibility study.

The goals of the EE/CA are to identify the objectives of the removal action (Section 3) and to analyze the effectiveness, implementability and cost of various alternatives that would meet these objectives (Sections 4 and 5). Based on this analysis, one removal action alternative is recommended for implementation (Section 6).

1.2 USEPA Consent Decree

This document has been prepared in accordance with Task 1 of the Statement of Work in Consent Decree No. 00-12471 between the United States Environmental Protection Agency (USEPA) and the Omega Chemical Site PRP Organized Group (OPOG). The Consent Decree was lodged on November 24, 2000 and entered into the US District Court on February 28, 2001.

Task 1 requires OPOG to "Design and Implement a Groundwater Containment and Mass Removal Treatment System in the Phase 1a Area". The Consent Decree defines the Phase 1a area as "the area of soil and groundwater contamination associated with the Omega Property and extending downgradient approximately 100 feet southwest of Putnam Street, Whittier, California". The Site location and vicinity are illustrated on Figure 1-1, and the Phase 1a area is illustrated on Figure 1-2.

1.3 Site Background

The following section is a summary of information regarding previous owners, operations, and known historical chemical use at and in the vicinity of the Site.

1.3.1 Owners and Operators

The subject Site located at 12504/12512 East Whittier Boulevard was first developed in 1951. The Site occupies Los Angeles County Assessor Tract No. 13486, Lots 3 and 4. The Site is approximately 41,000 square feet in area (200 feet wide x 205 feet long) and contains two structures – an approximate 140 by 50 foot warehouse and an approximate 80 by 30 foot administrative building. A loading dock is also attached to the rear of the warehouse. The exterior areas are concrete-paved and the Site is secured with a perimeter fence and locking gate.

Prior to construction of the Site buildings in July 1951, the Site was used for agriculture. The Site was operated by Sierra Bullets prior to 1963. During operation of the Sierra Bullet facility, a 500-gallon underground storage tank (UST) was utilized for storage of kerosene. The UST was subsequently removed in 1987 by Fred R. Rippy, Inc.

From 1976 to 1991 Omega Chemical Corporation operated a treatment and disposal facility for commercial and industrial solid and liquid wastes and a transfer station for storage and consolidation of wastes for shipment to other treatment and/or disposal facilities.

Van Owen Holdings LLC of Los Angeles, California purchased the property in 2003. Star City Auto Body occupies the warehouse (12504 Whittier Blvd.) and has performed auto body repair and painting on the premises. The auto body shop also leases the small paved parking lot north of the warehouse building for automobile parking. 3 Kings Construction has occupied the former administrative building (12512 Whittier Blvd.) and larger paved parking area south of the warehouse. The building is utilized for office space, and the parking lot is used for temporary storage and parking of construction vehicles and equipment.

1.3.2 Facility Processes and Chemical Usage

Limited information regarding volumes and types of wastes handled by the Omega Chemical Corporation is available for review. According to the Phase II Close Out Report (Hargis and Associates, England and Associates, October 1, 1996), Omega Chemical Corporation operated the facility for recycling and treatment of spent solvents and refrigerants. Drums and bulk loads of waste solvents and chemicals (primarily chlorinated hydrocarbons and chlorofluorocarbons) from various industrial activities were processed to form commercial products which were returned to generators or sold in the marketplace. An Operation Plan, prepared by Omega Chemical Corporation in 1990 for proposed expansion of the facility, provided a summary of current and proposed facility processes, tank capacities, incoming and facility-generated waste stream characteristics and handling practices, etc.

The majority of the 11 treatment units were located in the general area of the warehouse loading dock. As indicated in the Operation Plan, a total of 27 storage tanks with a combined storage capacity of 109,400 gallons were present at the facility in 1990. Six large, vertical storage tanks were arranged in an L-shaped pattern in the

southern corner of the Site. Five process tanks were located in the northern yard, and were arranged in a linear pattern along the side of the warehouse. The locations of the smaller storage tanks were not indicated in the Operation Plan.

Wastes accepted by Omega Chemical Corporation for recycling were broadly characterized as organic solvents and chemicals, and aqueous wastes with organic waste constituents. Sources of the incoming waste were a wide assortment of manufacturing and industrial processes (petroleum refining, rubber and plastics, chemicals, paper and allied products, furniture and fixture products, lumber and wood products, printing and publishing, textile mill products, food and kindred products, etc.). Most of the wastes reportedly arrived at the Site manifested under a few common EPA waste codes (e.g., D001, ignitable waste; and F001 through F005, halogenated and non-halogenated waste). According to the Operations Plan, typical Omega-generated waste consisted of the following: C6 to C11 aliphatics (43.4 percent), xylene (16 percent), toluene (7.2 percent), C9 to C10 alkyl benzenes (5.2 percent), isopropyl alcohol (5.1 percent), and a variety of other compounds.

1.4 Report Organization

This EE/CA is organized into nine major sections. Section 1 has presented the scope and objectives of this document as well as a brief Site background. Section 2 presents a Site description and a summary of Site characterization information. Section 3 describes the removal action scope and objectives. Removal action alternatives are described in Section 4 and evaluated independently in Section 4. Section 5 provides a relative evaluation of removal action alternatives and Section 6 then provides the rationale for selecting one of the alternatives as the recommended alternative. Section 7 provides a list of references that were used in preparation of the EE/CA, and figures and tables are presented in Sections 8 and 9, respectively.

Section 2

Section Two

Section 2

Site Characterization Summary

2.1 Location and Climate

The Omega Site is located at 12504/12512 East Whittier Boulevard, Whittier, California. The climate of the area is characterized as semi-arid, with an average annual precipitation of approximately 16 inches. Precipitation occurs mainly during the winter and spring months.

2.2 Surface Topography

The Site is relatively flat and is situated at an approximate elevation of 220 feet above mean sea level. Currently, two buildings (an office building and a warehouse) are located at the Site, with concrete paving covering exterior areas. Review of historical aerial photos (USEPA, 2000) indicated that exterior areas were primarily unpaved until approximately 1972.

2.3 Surrounding Land Uses

One commercial property (Skateland) and two industrial properties (Medlin & Son and Terra Pave) are immediately adjacent to the Site (southeastern, northwestern, and southwestern boundaries, respectively). The northeastern boundary of the Site is bordered by Whittier Boulevard and a frontage road. The three commercial/industrial properties immediately adjacent to the Site and nearby properties are discussed in the following sections.

2.3.1 Skateland

Skateland is located at 12520 Whittier Boulevard, adjacent to the southeastern boundary of the Site. The property consists of an indoor roller skating rink that is currently in operation and open to the public. Review of the aerial photographs indicates that the property was used for agricultural purposes in 1946. The building which presently occupies the property was observed on the 1956 photo. There were no documents or reports available for review regarding the Skateland property.

2.3.2 Terra Pave

The Terra Pave, Inc. facility is located at 12511 East Putnam Street, adjacent to the southwestern boundary of the Site. For information regarding historical activities at the Terra Pave property, a Phase 1 Environmental Site Assessment (ESA) Report prepared by Cardinal Environmental Consultants (Cardinal) on September 11, 1991, was reviewed.

The Phase I ESA Report was prepared for the New England Lead Burning Company (NELCO), which operated the site beginning in the mid-1950s. During the September 1991 site visit, the property was unoccupied. According to the report, NELCO purchased lead in sheets, pipe and solid rods and fabricated the desired product by burning (welding) the lead to the required shape. The welding was performed in the

building located along the northeastern portion of the property (Building 2). The type of work performed in the remaining building (Building 1) was primarily carpentry work and did not involve lead welding. Building 1 is a two-story concrete-block structure that was also used for offices and warehousing. Building 1 is currently utilized by Terra Pave for office space. Building 2 and the small parking lot south of Building 1 are currently leased from Terra Pave and occupied by Madsen Roofing. Figure 4 from the Phase 1 ESA Report is provided in Appendix A.

NELCO utilized the exterior of the property for storage of equipment and loading materials or finished goods for shipment. The report noted that the undeveloped portions of the property consisted of exposed soil and miscellaneous rubble. Drainage patterns incised in the soil were observed trending in a southerly direction towards Putnam Street.

The report briefly discussed the findings of environmental investigations performed between 1989 and 1991 to evaluate the property for the presence of residual lead. To mitigate this concern, NELCO subcontracted Vector Three Environmental Inc. of Brea, California, to clean the interior of all facilities and remove superficial lead from the topsoil. Remedial activities were monitored by Cardinal staff and confirmatory dust wipe and soil samples confirmed that remaining lead levels were very low. The environmental reports and sampling results were not available for review; therefore, lead levels prior to and after remediation and the depth of the soils removal are unknown.

2.3.3 Medlin & Son (Former Cal-Air)

The Medlin & Son (former Cal-Air facility) facility is located at 12484 Whittier Boulevard, adjacent to the northwestern boundary of the Site. For information regarding the former Cal-Air facility, a Phase I Environmental Assessment for the Evaluation of Potentially Hazardous Materials (Centec Engineering, Inc., August 5, 1997) was reviewed. The report was prepared for Maple Brothers Industrial, Inc. According to the report, a machine shop and office were constructed at the property in 1954, apparently by Roger Maples. The property was occupied by Accessory Products, Inc. until approximately early 1976. In September 1976, Cal-Air Conditioning Company added three new offices and occupied the property until 1996. The building on the property consists of a conglomeration of structural types, representing many additions and expansions during the years the property was occupied. A below-grade room and "test tunnel" is reportedly located along the southern side of the building. According to a City Building Department document, the test tunnel was to be used for non-hazardous test work on government projects. At the time of the assessment, the property was unoccupied and access to the test tunnel access was blocked by a heavy metal door and a large amount of water in the vault of the front entrance.

In October 1987, four USTs used to contain gasoline and diesel fuels were removed from the property by Toxguard Systems, Inc. Laboratory analytical results indicated 72 ppm hydrocarbons in one of the soil samples collected from under the USTs, with

no detectable hydrocarbon concentrations in the remaining seven samples submitted for analysis.

The property is currently occupied by Medlin & Son Engineering Services Inc. and is operated as a machine shop (screw machines, lathes and mills, tapping and threading, saw cutting, welding, etc.).

2.3.4 Nearby Properties

The Phase II Close Out Report provided information on four nearby properties located within an approximate one-half mile radius of the Omega Site. Fuel hydrocarbons (aromatic organics, total petroleum hydrocarbons, etc.) were detected in the groundwater underlying a former Chevron Station site located approximately 1,500 feet southwest (downgradient) of the Site. Fuel hydrocarbons were also detected in soil samples collected from a gasoline service station (G&M Oil Co.) located approximately 2,300 feet southeast (cross gradient) of the Site. Naphthalene, trichloroethene (TCE), tetrachloroethene (PCE), and other hydrocarbons have been detected at a Leggett & Platt furniture manufacturing facility approximately 2,000 feet northwest (cross-gradient) of the Site.

At a former automobile dealership (Jones Chevrolet) located 800 feet south of the Site, a variety of contaminants [fuel hydrocarbons, chlorinated organics, Freons, methyl tertiary butyl ether (MTBE), aromatic organics, etc.] have been detected in groundwater underlying the property.

2.4 Regional Geology and Hydrogeology

The Site is located in the Montebello Forebay area of the Central Groundwater Basin of the Coastal Plain of Los Angeles. The Montebello Forebay is an important area of groundwater recharge. Groundwater flow in the area is generally towards the southwest.

The Site is underlain by low permeability silty and clayey soils of the upper Pleistocene Lakewood Formation. The Lakewood Formation is locally derived from erosion of the Puente Hills to the northeast, and may be overlain by a thin cover of Holocene slopewash and alluvium that can be difficult to distinguish from the Lakewood Formation on the basis of lithology. Furthermore, local merging and interfingering of geologic units near the basin margin makes positive identification of individual geologic units encountered in borings problematic. The uppermost aquifer in the Site vicinity, probably the Gage aquifer in the lower portion of the Lakewood Formation, does not occur directly beneath the Site.

The nearest active downgradient water supply wells are located more than one mile from the Site. The closest active well (City of Santa Fe Springs well 30R3) is located on Dice Road by Burke Street, approximately 1.25 miles downgradient of the Site. According to the driller's log, this well is screened from 200 to 900 feet below ground surface (bgs) and at least two aquitards appear to be present between the shallowest aquifer and the top of the well screen.

2.5 Local Geology and Hydrogeology

This description of local geology and hydrogeology is based on an evaluation of lithologic logs from borings and wells advanced on-Site and downgradient of the Site. To date, the Omega PRP Organized Group (OPOG) has installed a total of 11 groundwater monitoring wells to investigate and characterize lithology and water quality in the Phase 1a and downgradient areas. Omega well and boring locations are illustrated on Figure 3-18 provided in Appendix A.

Lithologic data obtained from piezometers and wells installed along Putnam Street indicate that the uppermost aquifer in this area is comprised of sand, silty sand and well graded gravel containing significant silt. The aquifer is interbedded, and in the area between piezometers PZ1 and PZ2 contains a finer-grained interval separating the upper and lower portion of the aquifer. The deep well on Putnam Street (OW8b) indicates that a 26-foot thick clay separates the upper aquifer from the next deeper sandy interval that was screened in this well. This unit may correlate with the low permeability unit separating the Gage and Jefferson aquifers; however, the nearest regional cross-section in Bulletin 104 (State of California Department of Water Resources, 1961) suggests that this intervening unit is somewhat thicker.

A plan view location map and three detailed geologic cross-sections were included in the Revised Report Addendum for Additional Data Collection in the Phase 1a Area (CDM, 2005) as Figures 3-21 through 3-24. These four figures are provided in Appendix A. The three cross-sections were constructed approximately along the groundwater flow direction and orthogonal to this flow direction along Putnam Street. Cross-section A-A' (Appendix A, Figure 3-22) extends along an approximate groundwater flow line extending from OW7, upgradient of the Site, to OW4 downgradient of the Site. Shallow deposits in the vadose zone consist primarily of silt and clay deposits. This section illustrates the presence of the two aquifer zones present at the Site, separated by a low permeability confining zone. The upper aquifer zone appears to 'pinch out' in the area up gradient (east) of Putnam Street.

A relatively thick sand sequence is observed at OW4 and OW8 that thins dramatically at borings GP7 and GP1. This sandy zone is absent at boring GP2. The deeper sand zone is only observed at locations OW4 and OW8, which extended to a sufficient depth. Well OW1b extended to a similar depth; however, sandy lithologies were not encountered at this boring. Based on water levels at the OW4 and OW8 locations, where both deep and shallow zone completions are available, the groundwater elevations are significantly higher in the shallow aquifer. A similar downward gradient was observed at the cluster at OW1/1b. The varying water levels with depth indicate that a significant confining zone limits flow between these zones.

An additional cross-section, B - B', (Appendix A, Figure 3-23) was prepared extending from OW8b through H3, including wells OW1 and OW1b. This section also indicates that the upper zone pinches out. Well OW1b was drilled to approximately elevation 70 ft MSL and encountered only clayey lithologies. The interval in the sensing zone for this well does have small percentages of gravel interspersed in a clay

matrix near the bottom of the well; however, the small percentage of coarser material is not expected to significantly increase the permeability of this unit. This is a similar elevation as the deeper aquifer encountered at OW8b, which is screened from elevation 75 to 85 ft MSL in a well sorted fine to medium sand. Well OW1b has a sensing zone that likely intersects the uppermost portion of the same interval intersected at OW8b, implying that this deeper zone pinches out in a manner similar to the upper aquifer zone, or, if the deeper aquifer is present, it occurs at a greater depth. USEPA is currently installing additional wells to define groundwater flow directions in the Site vicinity. If these additional wells indicate that well OW8b is downgradient of the Site, then no further investigation of the potential for a deeper aquifer zone at the Site is warranted, since OW8b does not indicate the presence of high levels of contamination.

An additional cross-section was constructed approximately along Putnam Street, at a right angle to the general flow direction. Cross-section C-C' (Appendix A, Figure 3-24) incorporates boring logs available in USEPA files for other sites. This section indicates that the shallow aquifer may pinch out to the north, since it was not encountered in borings north of H-7. The shallow aquifer configuration shows the presence of a lower permeability zone splitting the upper aquifer north of PZ1. Boring 4 indicates a thick sand sequence suggesting that the lower permeability split was eroded, or never deposited, resulting in good hydraulic connection within the upper aquifer at this location. The uppermost sand unit within the upper aquifer appears continuous below the water table elevation from H7 at the northern end to B3 at the southern end of the section. A clayey gravel is present at a similar depth in OW3 that is also part of this unit; however, the presence of the clay matrix is likely to diminish the hydraulic conductivity of the unit. The cross section shows a clay unit at OW3 overlying this clayey gravel interval. The sand thickness increases, and interbedded clays are absent at boring H11, near Washington Street. The presence of possible multiple channel units with intervening clays appears to have localized transport of the volatile organic compound (VOC) plume at the Site to the area centered around OW8.

Figure 3-25 (Appendix A) provides a three-dimensional view of the distribution of lithologies at the Site. A column representing each boring location is color-coded to indicate the relative permeability of lithologies encountered at each location. A three-tiered classification system was used on this figure, with the yellow zones indicating intervals with the highest relative hydraulic conductivity, orange indicating intermediate values and blue indicating intervals with the lowest relative hydraulic conductivity. The highest relative hydraulic conductivity class was assigned to deposits that consisted primarily of sand or gravel, with limited silt and clay content. The intermediate hydraulic conductivity class was assigned to lithologies that included primarily sand or gravel, but with significant silt or clay, which will lower the hydraulic conductivity. The lowest hydraulic conductivity class was assigned to intervals that were primarily silt or clay. This figure illustrates the limited extent of the upper aquifer east of Putnam near the presumed source area. Boring logs along Putnam Street and downgradient show significant high and intermediate hydraulic conductivity material is present that pinches out to the east of Putnam Street. The

upper aquifer zone comprises a channel-like feature extending from near Putnam Street, toward the west. Information on the deeper aquifer is more limited, with only three wells extending to a sufficient depth. Based on this limited information, a similar trend occurs near the Omega Site east of Putnam Street, where sandy intervals are very limited.

Regional hydrogeologic information is inconclusive on the presence or absence of major regional named aquifers in this portion of the Whittier Area. A cross-section about 1.5 miles south of the Site is presented in Bulletin 104 (DWR, 1961) that suggests that the uppermost aquifers present are the Gage and Jefferson Aquifers. The upper aquifer at the Site may represent the Gage aquifer, while the lower aquifer is potentially the Jefferson aquifer.

2.6 Water Level and Groundwater Elevation Results

Water level measurements were collected and groundwater elevation contour maps were prepared for measurements collected monthly during May 2001 through April 2002, and semi-annually during April 2002 through August 2004. The direction of groundwater flow in the upper aquifer has been consistently towards the southwest during all 17 water level monitoring events (CDM, 2005). The groundwater elevation contour map for August 2004 (Figure 3-18) is provided in Appendix A. Insufficient water level data are available in the lower aquifer to define the groundwater flow direction. As directed by USEPA, OSVOG (Omega Small Volume Group) is currently proposing to install additional shallow and deep wells in the area downgradient of the Site. These wells will allow better definition of flow pathways in both the shallow and deeper aquifer zones.

There is a noticeable change in hydraulic gradient in the vicinity of Washington Boulevard and the OW4 monitoring well cluster, which corresponds to the observed transition from finer-grained subsurface lithology in the area northeast of Washington Boulevard to coarser-grained subsurface lithology in the area southwest of Washington Boulevard. During the August 2004 sampling event, the hydraulic gradient upgradient of cluster well OW4 was approximately 0.01 ft/ft, and downgradient of cluster well OW4 it was approximately 0.003 ft/ft. A similar trend was observed during the August 2001 sampling event; with a hydraulic gradient of approximately 0.01 ft/ft up gradient of cluster well OW4 and 0.002 ft/ft downgradient of cluster well OW4.

As indicated by review of the hydrographs provided in Appendix G of the Revised Report Addendum, water levels have generally been declining throughout most of the monitored period (e.g., 74.19 feet bgs in well OW1 during May 2001 to 78.84 bgs during August 2004). During the monthly monitoring that occurred during mid-2001 to mid-2002, water levels were generally slightly higher during spring and summer months, and slightly lower during fall and winter months.

As observed at the three locations where shallow and deeper well pairs (OW1, OW4 and OW8) are present, groundwater elevations in the deeper wells were consistently

deeper than the elevations observed at the shallow wells at those locations. Appendix G (CDM, 2005) presents each of these paired wells on the same figure to allow comparisons between the well pairs. Also, as water levels have dropped over time in wells OW1/ OW1b and OW4a/ OW4b, the differences in head between the monitored zones have increased at both locations. For example, at OW1/OW1b during May 2001, the head difference between the two zones was 3.43 feet. During the August 2004 sampling event, the head difference between the two wells was 9.28 feet. The well pair at OW4a/OW4b exhibited a similar trend, with a head difference of 3.76 feet in May 2001 and 8.99 feet in August 2004. The difference in head at location OW8/OW8b during August 2004 was 17.4 feet. The August 2004 sampling event was the initial sampling of newly-installed well OW8b. Subsequent sampling at OW8/OW8b will allow for additional evaluation of head differences at that location. The most recent measurements, taken in February, 2005, show an increase in water level in the deeper zone monitoring wells that decreased the head difference between the upper and lower aquifers. However, the vertical gradient remained downward.

This head difference suggests that significant hydraulic separation exists between the shallow and deeper screened zones. Although a downward gradient exists from the shallow zone to the deep formation, the water quality results from the three well pairs show that the hydraulic separation between the two zones limits downward vertical migration.

2.7 Aquifer Characteristics

Single borehole and multi-well aquifer tests were conducted by OPOG between 1999 and 2003. Estimates of transmissivity were obtained for the upper aquifer in wells along Putnam Street. The upper aquifer transmissivity in the Phase 1a area ranged from 563 to 810 ft² /day. Transmissivity increased in the downgradient direction, with a value of nearly 2,700 ft² /day estimated at OW4a. Design of a hydraulic containment system for the upper aquifer in the vicinity of Putnam Street will focus on the sand channel deposit that appears to be transmitting the majority of the contaminant mass from the Site.

2.8 Groundwater Sampling Results

Of the analytes tested in the groundwater at the Site, chlorinated VOCs and 1,4-dioxane have been detected more frequently and at higher concentrations in the Phase 1a area; therefore, they are the primary compounds of concern. Tables summarizing groundwater analytical results for groundwater samples collected from Omega wells from 1996 to the present are provided in Appendix A.

Based on observations at three locations where a water table and deeper well pair are present (OW1/OW1b, OW4a/OW4b, and OW8/OW8b), chlorinated VOC concentrations were observed to decline with depth and appear to be of limited vertical extent. Concentrations were also observed to decline with increased distance downgradient from the Site. Aromatic organics, semi-volatile organic compounds (SVOCs), pesticides, and metals were detected sporadically and at relatively low

concentrations in groundwater samples collected from the Phase 1a area wells, therefore, they are not considered compounds of concern.

As discussed previously, based on evaluation of the lithologic, aquifer testing, and groundwater sampling results, there appears to be a higher-permeability channel deposit immediately downgradient of the Site in the vicinity of well OW8 on Putnam Street. Relatively higher (compared to well OW2 to the north and well OW3 to the south) VOC and 1,4-dioxane concentrations were also detected in this area. Samples from the current monitoring program and early Site investigations indicate that migration of chlorinated VOCs from the Site occurs primarily within the noted higher permeability deposits that extend from approximately the location of temporary probe H7 on the north to H11, near the intersection of Washington and Putnam. Based on observed concentrations, most contaminant mass is transmitted through the center of this feature, near the location of well OW8.

Groundwater sampling results indicate that the highest contaminant concentrations are associated with the former source area locations that are up gradient of Putnam Street, and that this contamination is predominantly limited to the shallower portions of the aquifer. These contaminants include various chloroethene parent compounds (PCE and TCE) and their primary daughter products (cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride [VC]); chloroethane parent compounds (PCA, 1,1,1-TCA, and 1,1,2-TCA) and their daughter products (1,1-DCA, 1,2-DCA, and 1,1-DCE [abiotic hydrolysis of 1,1,1-TCA]); chloromethanes [carbon tetrachloride (CTC), chloroform (CFM), and methylene chloride (MC)], and Freons. The compound 1,4-dioxane was also found at elevated concentrations on-Site at the location of boring GP3A.

The highest VOC concentrations are found within the shallow groundwater plume as evidenced by data from well OW1 (screened from 62.5 to 77.5 feet bgs) during the August 2004 semi-annual sampling event. In particular, the data indicate elevated concentrations of the parent-compounds PCE (150,000 ug/L) and 1,1,1-TCA (12,000 ug/L), with TCE (3,500 ug/L) and 1,1-DCE (2,000 ug/L) present at substantially lower concentrations and likely as biotransformation daughter-products, respectively. The concentration of PCE detected at monitoring well OW1 (150,000 ug/L) represents 75 percent of the aqueous solubility of PCE (200,000 ug/L) and therefore provides strong evidence for the presence of a dense non-aqueous phase liquid (DNAPL) within this area of the Site. Conversely, groundwater data from monitoring well OW1b (screened in a deeper interval from 110 to 120 feet bgs) during the August 2004 semi-annual sampling event indicate only minimal VOC detections at this deeper interval. For example, PCE was detected at a concentration of 87 ug/L, TCE at a concentration of 2.8 ug/L, and 1,1-DCE at a concentration of 2.2 ug/L.

1,4-dioxane was detected in Site well OW1 at concentrations ranging from 3,300 ug/L (February 2005) to 52,000 ug/L (February 2003). Concentrations in deeper well OW1b ranged from 15 ug/L (February 2005) to 60 ug/L (August 2002). Concentrations in Putnam Street well OW8 ranged from 98 ug/L (August 2003) to 6,900 ug/L

(February 2005). 1,4-dioxane was not detected in recently-installed deeper well OW8b during sampling performed in August 2004 and February 2005.

Due to the significant depths at which water is first encountered at the Site (i.e., approximately 75 feet in the vicinity of OW1) and the predominance of fine-grained silts and clays in the subsurface, it is likely that a large fraction of any DNAPL release at the Site would be bound up in the unsaturated zone soils. Furthermore, groundwater data collected at OW1 indicate variability in PCE and TCE concentrations since 1996, which suggests that the VOC concentrations in groundwater are more likely to be controlled by leaching of contamination from the unsaturated zone (i.e., through DNAPL/water interactions and vapor/water interactions) rather than by dissolution from DNAPL within the saturated zone.

2.9 Streamlined Risk Evaluation

The primary objective of the streamlined risk evaluation (SRE) is to assess existing and imminent risks to human health and the environment at the Site as they pertain to the EE/CA removal action. At the Omega Site, risks from contaminated groundwater could theoretically result from use of groundwater for domestic or other purposes and from volatilization of groundwater contaminants into ambient and indoor air. A separate risk assessment evaluating risks from soil and soil gas will be provided in the On-Site Soils RI/FS. Therefore, this SRE does not address risks associated with these media. Because the Omega facility is located in an urban area that has been developed for decades, provides no suitable habitat, and contaminated subsurface soils are covered with buildings, asphalt, or concrete, ecological impacts from the facility are not expected and are not evaluated.

The following documents and others cited within this section form the basis for the SRE:

- Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A). Interim Final. EPA/5401/1-891002. December 1989.

2.9.1 Site Conceptual Exposure Model

The site conceptual exposure model is a description of potential exposure pathways associated with the site, including potential sources of contamination, transport mechanisms, exposure routes, and potentially exposed populations. Only exposure pathways likely to be complete and to contribute significantly to overall exposure are evaluated quantitatively in the SRE.

A complete exposure pathway would consist of the following four elements:

- A source and mechanism of release of chemicals to the environment
- A transport medium for the released chemical

- An exposure point (the point of potential contact between receptor and medium)
- An exposure route (e.g., inhalation, ingestion)

The site conceptual exposure model for the Site is illustrated in Figure B-1. Potentially exposed populations are assumed to be an on-site industrial worker, an off-site industrial worker, an on-site construction worker, and an on-site recreational visitor. Currently, no plans exist for residential development at the Site, and the Site location suggests that residential development in areas adjacent to the Site is unlikely.

2.9.1.1 Ingestion and Dermal Contact

Currently, groundwater within the contaminant area (Gage aquifer) is not used for domestic, industrial, or agricultural purposes. Future use of groundwater for potable purposes is also unlikely due to high concentrations of TDS. No evidence suggests that contamination extends to any potable aquifer that underlies the Gage aquifer. If future data collection indicates that downward vertical migration has occurred, then future risk evaluations will need to address a potential drinking water pathway. A stepwise human health risk ratio evaluation is provided in Appendix B to provide Site management with additional information regarding potential health risk issues at the Site if groundwater is used for potable use in the future. Currently, this groundwater exposure pathway for ingestion is incomplete for all potential receptors.

Groundwater is 70 feet below ground surface and construction workers will not encounter groundwater in their excavations. Currently, this groundwater exposure pathway for dermal contact is incomplete.

2.9.1.2 Inhalation of Indoor Air – Volatilization during Groundwater Use

As noted above, groundwater within the contaminant area (Gage aquifer) is currently not used for any purpose nor is it likely to be used for potable use in the future due to high concentrations of TDS. As such, this groundwater exposure pathway is incomplete.

2.9.1.3 Inhalation of Indoor Air - Soil Vapor

The Omega property and adjacent areas between the property and Putnam Street overly groundwater which is contaminated with VOCs. Theoretically, these COPCs could partition from groundwater via volatilization and migrate through subsurface soils and foundations and into indoor air. Recreational visitors and industrial workers could potentially be exposed through inhalation of soil vapors into indoor air. However, in order to completely evaluate the pathway for volatilization of groundwater contaminants and subsequent intrusion of vapors into indoor spaces, exposure to soil gas should be evaluated simultaneously. Quantification of both soil gas and groundwater risks is a way of evaluating which contamination source provides the greater health threat. Therefore, this groundwater pathway will be evaluated in the separate risk assessment to be prepared for the On-Site Soils RI/FS.

In addition, as will be discussed further in Section 3.1, the EE/CA removal action that is the purpose of this report is intended as a migration control measure, to minimize the transport of VOCs in groundwater from the Omega property to down-gradient areas. In parallel with this EE/CA action, an On-Site soils RI/FS is being completed, toward the selection and implementation of an appropriate remedy. A risk assessment is an integral component of that work, and the On-Site Soil RI/FS risk assessment will include an evaluation of exposure via vapor intrusion.

2.9.1.4 Inhalation of Ambient Air

Volatile COPCs in the subsurface could migrate to the surface and be released to ambient air. Construction workers and on-site industrial workers who are outdoors could inhale these chemicals. However, because the atmosphere outside has no boundaries, any vapors that rise to surface and are released to ambient air will be quickly dispersed. Vapors migrating to indoor air are likely to present a more important exposure pathway for commercial/industrial workers because they will spend large amounts of time indoors, and because the building and foundation represent a "trap" for migrating gases. Conclusions developed for indoor exposure to vapors should be protective of ambient exposure to vapors. Indoor air exposure will be evaluated in the separate risk assessment to be prepared for the On-Site Soils RI/FS.

2.9.2 Summary

No groundwater exposure pathways as they pertain to the EE/CA removal action are complete for the potential exposed populations. No current or foreseeable future risks are apparent due to existing contamination in the Gage aquifer. As additional information for the risk manager, Appendix B presents some hypothetical risk calculations that can be used to judge magnitude of impacts to the aquifer. As stated previously, a separate risk assessment of exposure to soil and soil gas at the Site will be prepared for the On-Site Soils RI/FS. Volatilization of groundwater contaminants and subsequent intrusion of vapors into indoor spaces will be evaluated with the exposure to soil gas.

3

Section
Three

Section 3

Section 3

Identification of Removal Action Scope and Objectives

3.1 Removal Action Scope and Objectives

In general terms for this Site, the scope of the non-time-critical removal action is to minimize migration of contaminated groundwater. The scope therefore covers only groundwater on-Site and groundwater migrating off-Site (i.e., OU1) and recognizes that additional remedial actions are likely to be taken to address on-Site soils contamination as part of the on-Site soils RI/FS. Additionally, groundwater downgradient of Putnam Street will be addressed by EPA's OU2 RI/FS.

The specific Remedial Action Objectives (RAOs) for this EE/CA are:

1. Provide horizontal and vertical containment within the Phase 1a Area of groundwater contamination associated with the Omega property
2. Meet air emission and water treatment standards associated with the treatment and/or reuse of extracted groundwater.

Though not specifically a RAO, operation of a groundwater extraction and treatment system will also result in the removal of contaminant mass from the groundwater in the Phase 1a Area.

With regard to the implementation schedule for the selected removal action, the design of the selected removal action will begin after the following components of the EE/CA process are completed:

- EPA review of the EE/CA and incorporation of EPA comments
- Public comment of EE/CA (at least a 30-day period)
- Response to public comments
- EPA preparation of the Action Memorandum

It is currently anticipated that the 30 percent design of the removal action will be submitted to the EPA for review September 2005. It is further anticipated that startup of the removal action (i.e., completion of its construction) will occur in March 2006.

3.2 Potential Applicable or Relevant and Appropriate Requirements

This evaluation identifies potential Applicable or Relevant and Appropriate Requirements (ARARs) pertinent to the identification, screening and selection of removal action alternatives for the Omega Site groundwater remedy. Other criteria or

guidelines to be considered (TBCs) in selecting an appropriate action are also identified.

3.2.1 Definition of ARARs and Other Criteria or Guidelines to be Considered (TBCs)

Section 121(d) of CERCLA requires that remedial actions at CERCLA sites attain (or justify the waiver of) any federal or state environmental standards, requirements, criteria, or limitations that are determined to be legally applicable or relevant and appropriate. Federal ARARs may include requirements under any of the federal environmental laws (e.g., the Clean Air Act [CAA], the Clean Water Act [CWA], and the Safe Drinking Water Act [SDWA]). State ARARs may only include promulgated, enforceable environmental or facility-siting laws that are more stringent or broader in scope than federal requirements. Many California state laws give enforcement authority to local agencies which develop regulations that implement state requirements. As a result, some local regulations can also be ARARs.

An ARAR may be either "applicable," or "relevant and appropriate," but not both. If there is no specific federal or state ARAR for a particular chemical or remedial action, or if the existing ARARs are not considered sufficiently protective, then other criteria or guidelines to be considered (TBCs) may be identified and used to ensure the protection of public health and the environment. According to the NCP (40 CFR part 300), "applicable," "relevant and appropriate", and "to be considered" are defined as follows:

- Applicable requirements are those cleanup standards, standards of control, or other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable.
- Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be relevant and appropriate. In some circumstances, a requirement may be relevant but not appropriate for the site-specific situation and thus not considered as an ARAR.
- TBCs consist of advisories, criteria, or guidance developed by EPA, other federal agencies, or states that may be useful in developing CERCLA remedies. The TBC values and guidelines may be used as EPA deems appropriate.

In determining whether a requirement is applicable or both relevant and appropriate, EPA considers the remedial actions contemplated, the hazardous substances present, the characteristic of the hazardous substances, the physical characteristics of the site, and other appropriate factors.

Pursuant to CERCLA §121 and the NCP, only substantive requirements are ARARs. In addition, under CERCLA §121(e) and the NCP (40 CFR Part 300.68(a)(3)), federal, state, and local permits are not required for those portions of a CERCLA cleanup that are conducted entirely onsite, as long as the actions are selected and carried out in compliance with CERCLA §121.

3.2.2 Identification of ARARs

ARARs may be placed into three categories:

- Chemical-specific
- Location-specific
- Action-specific

Chemical-specific ARARs are health- or risk-based concentration limits, numerical values, or methodologies for various environmental media (i.e., groundwater, surface water, air, and soil) that are established for a specific chemical that may be present in a specific media at the site, or that may be discharged to the site during remedial activities. These ARARs set limits on concentrations of specific hazardous substances, pollutants, and contaminants in the environment.

Location-specific requirements set restrictions on certain types of activities based on site characteristics. Federal and state location-specific ARARs are restrictions placed on the concentration of a contaminant or the activities to be conducted because they are in a specific location. Examples of specific locations possibly requiring ARARs may include floodplains, wetlands, historic places, and sensitive ecosystems or habitats.

Action-specific requirements are technology- or activity-based requirements that are triggered by the type of remedial activities under consideration. Examples are RCRA regulations for waste treatment, storage, or disposal.

The following groups of ARARs and TBCs were considered during the identification process:

- Federal, California, and local requirements (applicable, relevant and appropriate, or to be considered)
- Federal and California criteria, advisories, and guidance documents (to be considered)

3.2.3 Potential Chemical-Specific ARARs

Chemical-specific ARARs are health- or risk-based concentration limits or methodologies for various environmental media (i.e., groundwater, surface water, air, and soil) that are established for a specific chemical that may be present in a specific media at a site, or that may be discharged to a site during remedial activities. A removal action for the Omega site has not yet been selected. As a result, all chemical-specific ARARs identified in this section are preliminary. A final determination of the ARARs for this site may not occur until after completion of the removal action and implementation of a post-removal action monitoring program. In addition, since the removal action established for the Omega site will be an interim action, chemical-specific requirements will likely not be ARARs in the selected interim remedy for the purpose of establishing cleanup levels throughout the aquifer (see 55 Fed. Reg. 8755).

The contaminants of potential concern (COPC) for the Omega Site are those contaminants identified in the groundwater underlying the Site. A tabular summary of Omega Site COPCs is provided in Appendix B. The chemical-specific federal and state ARARs that address the contaminants of potential concern are discussed below.

3.2.3.1 Federal Safe Drinking Water Act

EPA has established Maximum Contaminant Levels (MCLs) (40 CFR Part 141) under the Safe Drinking Water Act (SDWA) to protect public health from contaminants that may be found in drinking water sources. MCLs are enforceable standards that are applicable at the tap for water that is delivered directly to 25 or more people or to 15 or more service connections. MCLs are potentially applicable to groundwater that is treated and served as drinking water. MCLs are potentially relevant and appropriate to any water that is discharged into the environment and to in-situ groundwater at or beyond the edge of a containment area (CERCLA Compliance With Other Laws Manual [OSWER Dir. 9234.1-01, Aug. 1988]).

Under the SDWA, EPA has also designated Maximum Contaminant Level Goals (MCLGs) (40 CFR Part 141) which are health-based goals that may be more stringent than MCLs. MCLGs are based entirely on health considerations and do not take cost or feasibility into account. MCLGs are set at levels, including an adequate margin of safety, where no known or anticipated adverse health effects would occur. MCLGs are not applicable or relevant and appropriate because the MCLGs for the contaminants of concern at the Omega site are either zero (40 CFR Section 300.430(e)), or are equal to the MCLs.

3.2.3.2 California Safe Drinking Water Act

California has established standards for sources of public drinking water, under the California Safe Drinking Water Acts of 1976 and 1996 (Health and Safety Code (H&SC) §§ 4010.1, 4026(c), and 116365). Some state MCLs are more stringent than the corresponding federal MCLs. In these instances, the more stringent MCLs would take precedence. There are also some chemicals that lack federal MCLs. Where state MCLs

exist, they may also be ARARs for these chemicals. MCLs are potentially applicable to groundwater that is treated and served as drinking water.

3.2.3.3 Water Quality Control Plan for Los Angeles Region

The Los Angeles plan (commonly referred to as the "Basin Plan") designates the beneficial uses of groundwater in the Los Angeles coastal plain to be municipal and domestic, agricultural, industrial service, and industrial process supplies (California Water Code §13240 et seq.). The Basin Plan establishes beneficial uses of ground and surface waters, establishes water quality objectives, including narrative and numerical standards, establishes implementation plans to meet water quality objectives (WQOs) and protect beneficial uses, and incorporates statewide water quality control plans and policies. The WQOs for groundwater are based on the primary MCLs. Any activity that may affect water quality must not result in the water quality exceeding the WQOs. The Basin Plan is also discussed as a location-specific ARAR in Section 3.2.5.2.

3.2.4 Potential Location-Specific ARARs

Federal and state location-specific ARARs are restraints placed on the concentration of a contaminant or the activities to be conducted because they are in a specific location. Examples of location-specific ARARs are requirements restricting actions in, or otherwise protecting, floodplains, wetlands, historic places, and sensitive ecosystems or habitats. Location-specific ARARs are really a subset of action-specific ARARs, in that they do not drive the need for a CERCLA action to occur, but, if CERCLA action is otherwise appropriate, may constrain the range of appropriate action.

3.2.4.1 National Historic Preservation Act

This statute and implementing regulations (16 U.S.C. § 470, 40 CFR Part 6.310(b), 36 CFR Part 800), require federal agencies or federal projects to take into account the effect of any federally-assisted undertaking or licensing on any district, site, building, structure, or object that is included in, or eligible for, the Register of Historic Places. If remedial action is likely to have an adverse effect on any cultural resources which are on or near the Site, EPA should examine whether feasible alternatives exist that would avoid such effects. If effects cannot reasonably be avoided, measures should be implemented to minimize or mitigate the potential effect.

The National Historic Preservation Act (NHPA) regulations reserve formal determination of eligibility for the National Register of Historic Places and "no adverse effects" determinations for federal agencies.

3.2.4.2 Archaeological and Historic Preservation Act

This statute and implementing regulations (16 U.S.C. § 469, 40 CFR Part 6.301(c)) establish requirements for the evaluation and preservation of historical and archaeological data that may be destroyed through alteration of terrain as a result of a federal construction project or a federally licensed activity or program.

3.2.4.3 Historic Sites, Buildings, and Antiquities Act

This standard (16 U.S.C. §§ 461-467, 40 CFR Part 6.301(a)) requires federal agencies to consider the existence and location of landmarks on the National Registry of Natural Landmarks to avoid undesirable impacts on such landmarks. Remedial alternatives contemplated for the Omega site are not anticipated to affect any of the facilities regulated under the above act.

3.2.4.4 Location Standards for TSD Facilities

California Code of Regulations, Title 22, Section 66264.18 establishes location standards for Hazardous Waste Treatment, Storage, and Disposal Facilities (TSDFs). These standards may be applicable to groundwater extraction and treatment facilities. Subsection 66264.18(a) prohibits the placement of TSDFs within 200 feet of a fault displaced during the Holocene epoch. Subsection 66264.18 (b) requires TSDFs located within a 100-year floodplain be capable of withstanding a 100-year flood.

3.2.4.5 Endangered Species Act

This statute and implementing regulations (15 U.S.C. §§ 1531-1544, 50 CFR Part 402 40 CFR Part 6.302(h)) require that any federal activity or federally authorized activity may not jeopardize the continued existence of any threatened or endangered species or destroy or adversely modify the critical habitat of a listed species. Compliance with this requirement involves consultation between EPA and the U.S. Fish and Wildlife Service, resulting in a determination as to whether there are listed or proposed species or critical habitats present at or near the Omega site and, if so, whether any proposed activities will impact such wildlife or habitat.

3.2.4.6 California Fish and Game Code

California Fish and Game Code Sections 2080, 5650(a), (b), and (f), 12015, and 12016 prohibit the discharge of harmful quantities of hazardous materials into places that may deleteriously affect fish, wildlife, or plant life. These sections may be applicable if the selected removal action provides for the discharge of extracted and treated groundwater to a surface water body. Section 3503 prohibits take, possession, or needless destruction of any bird nests and eggs, except as provided by the Fish and Game Code or regulations. Implementation of the final remedy will comply with this requirement.

3.2.5 Potential Action-Specific ARARs

Action-specific ARARs are usually technology- or activity-based requirements for remedial activities. Action specific ARARs described in this section are intended to address those actions resulting from implementation of remedial alternatives. Remedial alternatives for the Omega site could require the construction and operation of groundwater extraction facilities, groundwater treatment facilities (e.g., air stripping with off-gas control), and pipelines and other conveyance facilities needed to deliver treated water to an industrial water supply system, municipal wastewater collection and treatment system, surface water drainage system, or spreading basin. A brief description of potential action-specific ARARs is presented below.

3.2.5.1 Local Air Quality Management

One potential VOC treatment technology is air stripping. Air emissions from air strippers are regulated by the California Air Resources Board, which implements the federal Clean Air Act (CAA) as well as the state H&SC through local air quality management districts. Local districts can add additional regulations to address local air emission concerns. The local air district for the EMOU area is the South Coast Air Quality Management District (SCAQMD). The SCAQMD has adopted several rules that may be ARARs for air stripper emissions.

SCAQMD Regulation XIII, comprising Rules 1301 through 1313, establishes new source review requirements. Rule 1303 requires that all new sources of air pollution in the district use best available control technology (BACT) and meet appropriate offset requirements. Emissions offsets are required for all new sources that emit in excess of one pound per day.

SCAQMD Rule 1401 requires that best available control technology for toxics (T-BACT) be employed for new stationary operating equipment, so that the cumulative carcinogenic impact from air toxics does not exceed the maximum individual cancer risk limit of 10 in 1 million (1×10^{-5}). Many of the contaminants found in the Omega site groundwater are air toxics subject to Rule 1401.

SCAQMD Rules 401 through 405 may also be ARARs. SCAQMD Rule 401 limits visible emissions from a point source; Rule 402 prohibits discharge of material that is odorous or causes injury, nuisance, or annoyance to the public; Rule 403 limits fugitive dust; Rule 404 limits particulate matter in excess of concentration standard conditions; and Rule 405 limits solid particulate matter including lead and lead compounds.

These regulations may be applicable if the selected remedy involves the removal of VOCs from groundwater through air stripping.

3.2.5.2 Federal Clean Water Act and California Porter-Cologne Water Quality Act

California's Porter-Cologne Water Quality Act incorporates the requirements of the federal Clean Water Act (CWA) and implements additional standards and requirements for surface and groundwaters of the state. This Act gives authority to the Los Angeles Regional Water Quality Control Board (RWQCB) to formulate and adopt a water quality control plan for its region; the RWQCB has adopted the Los Angeles Region Water Quality Control Plan (Basin Plan). The Basin Plan identifies the beneficial uses of surface and groundwaters in specific watersheds and water quality objectives necessary to protect these beneficial uses.

The RWQCB regulates discharges to surface and groundwaters through the issuance of National Pollutant Discharge Elimination System (NPDES) permits, issued pursuant to CWA requirements, Waste Discharge Requirements (WDR), or Water Reclamation Requirements (WRR) for treated wastewater.

In Issuing a WDR or WRR, the RWQCB considers the beneficial uses and water quality objectives for the affected water body as well as existing water quality data and mixing and dilutionary effects. Consequently, the Basin Plan's water quality objectives for receiving water bodies may be ARARs if the selected removal action provides for the discharge of extracted groundwater.

The Basin Plan also incorporates the State Water Resources Control Board (SWRCB) policy "Statement of Policy with Respect to Maintaining High Water Quality in California" (Resolution 68-16). Resolution 68-16 requires that existing water quality be maintained unless it is demonstrated that a change will benefit the people of California, will not unreasonably affect present or potential uses, and will not result in water quality less than prescribed by other State policies. Any activity that may increase the volume or concentration of a waste discharged to surface or groundwater is required to use "best practical treatment or control." Resolution 68-16 may be applicable if the selected removal action provides for the discharge of extracted groundwater to a surface water body or back to groundwater. Resolution 68-16 has also commonly been applied to the migration of existing groundwater contamination plumes.

The Basin Plan also incorporates the SWRCB's "Policies and Procedures for Investigation and Cleanup and Abatement of Discharges under Water Code Section 13304" (Resolution Number 92-49). Subsection III.G of Resolution 92-49 requires attainment of background water quality or, if background levels cannot be restored, the best quality of water that is reasonable. Case-by-case cleanup levels for the restoration of water quality must, at a minimum:

- Be consistent with maximum benefit to the people of the state
- Not unreasonably affect present and anticipated beneficial use of the waters
- Not result in water quality less than that prescribed in the Basin Plan and policies adopted by the SWRCB and RWQCB

Resolution 92-49 may be relevant and appropriate to the Omega site groundwater.

3.2.5.3 SWRCB Resolution No. 88-63

This policy specifies that ground and surface waters of the state are either existing or potential sources of municipal and domestic supply except water supplies with:

- Total dissolved solids exceeding 3,000 milligrams per liter, or
- Natural or anthropogenic contamination (unrelated to a specific pollution incident) that cannot reasonably be treated for domestic use using either best management practices (BMPs) or best economically achievable treatment practices, or
- The water source does not provide a sustained yield of 200 gallons per day.

The requirement appears to be applicable because groundwater underlying the Site meets the criteria as a potential source for drinking water.

3.2.5.4 California Code of Regulations 27 CCR §20380, 20400, 20410, and 20415

These regulations require corrective action monitoring to demonstrate completion of the selected remedy for the Site. Corrective action measures may be terminated when all COC concentrations are reduced below their respective concentration limits throughout the entire zone affected by the release. §20410 requires monitoring for compliance with remedial action objectives for years from the date of achieving cleanup standards.

3.2.5.5 California Hazardous Waste Management Program

The federal Resource Conservation and Recovery Act (RCRA) establishes requirement for the management and disposal of hazardous wastes. In lieu of the federal RCRA program, the State of California is authorized to enforce the Hazardous Waste Control Act, and implementing regulations (California Code of Regulations (CCR) Title 22, Division 4.5), subject to the authority retained by EPA in accordance with the Hazardous and Solid Waste Amendments of 1984 (HSWA). California is responsible for permitting treatment, storage and disposal facilities within its borders and carrying out other aspects of the RCRA program. Some of the Title 22 regulations may be ARARs if the selected removal action for the Omega site results in the generation or disposal of hazardous wastes.

Hazardous Waste Generator Requirements

CCR Title 22 establishes requirements applicable to generators of hazardous waste. Implementation of certain potential removal action alternatives may generate hazardous waste as a result of groundwater monitoring and well installation (e.g., contaminated soil and groundwater and used personal protective equipment). Alternatives involving groundwater treatment may also generate hazardous waste as a result of groundwater treatment to remove VOCs (e.g., spent carbon). These requirements may be applicable to a removal action at the Omega site.

Land Disposal Restrictions

CCR Title 22 defines hazardous waste that cannot be disposed of to land without treatment. Land Disposal requirements may be applicable to the disposal of spent carbon generated during the treatment of groundwater for removal of VOCs and the disposal of residuals associated with groundwater monitoring and well installation (e.g., contaminated soil and groundwater, used personal protective equipment).

3.2.5.6 Clean Water Act (CWA) and CSDLAC Wastewater Ordinance

Under 40 CFR Part 403, standards are set to control the introduction of pollutants to publicly-owned treatment works (POTWs). These standards are implemented by the local POTW, which is the County Sanitation Districts of Los Angeles County (CSDLAC) for the Omega site.

In addition to the general standards and requirements of the CWA, the CSDLAC Wastewater Ordinance specifies additional limitations, standards, and requirements for the discharge of wastewater. Fees for sewer connections and wastewater concentration and flow may also be applicable.

Finally, the CSDLAC policy of only accepting groundwater as a last resort may be applicable. This policy is contained in Section 305 of the CSDLAC Wastewater Ordinance (November 1, 1989) and in "Guidelines for the Discharge of Rainwater, Storm Water, Groundwater, and Other Water Discharges."

The CSDLAC has established effluent limitations for accepting groundwater discharges (listed in Documentation To Be Provided To Pursue The Discharge Of Groundwater To The Sanitation District's Sewerage System"). These limits are as follows:

- pH greater than 6
- Dissolved sulfides less than 0.1 mg/L
- TDS less than 1,000 mg/L if discharged to a water reclamation plant (if the concentrate from a membrane separation process were discharged to an interceptor line leading to the Carson Treatment Plant, no TDS limitation would apply)
- ASTM closed cup flash point greater than 60°C
- Total VOCs and SVOCs less than 1.0 mg/L (per EPA Methods 601 & 602 or 624 & 625)
- Cyanide (Total) less than 10 mg/L
- Arsenic less than 3 mg/L
- Cadmium less than 15 mg/L
- Chromium (Total) less than 10 mg/L
- Copper less than 15 mg/L
- Lead less than 40 mg/L
- Mercury less than 2 mg/L
- Nickel less than 12 mg/L
- Silver less than 5 mg/L
- Zinc less than 25 mg/L

3.2.5.7 California Well Standards

The California Department of Water Resources document *California Well Standards Bulletin Nos. 74-81 and 74-90* includes construction standards (e.g., casing specifications, annular sealing materials, etc.) for the installation of extraction and monitoring wells. The construction standards should be considered for extraction and monitoring well installations.

3.3 Identification of Guidance and Criteria to be Considered (TBCs)

Other standards, criteria, or guidance to be considered are federal, state, or local advisories or guidance that do not have the status of potential ARARs. If there are no specific federal or state ARARs for a particular chemical or removal action, or if the existing ARARs are not considered sufficiently protective, then guidance or advisory criteria may be identified and used to ensure the protection of public health and the environment. TBCs may provide health effects information, technical information on performing or evaluating site investigations or remedial actions, and useful policies for dealing with hazardous substances.

3.3.1 State Action Levels (ALs) and Public Health Goals (PHGs)

The state has also developed numerical criteria as state action levels (ALs) for selected chemicals in drinking water for which MCLs have not yet been established. Since early 1989, numerous state ALs have been promulgated as state MCLs. The ALs referred to here are those that have never been promulgated.

Although drinking water ALs are not specifically listed in laws or regulations, they are derived under general protection of the public in the California Safe Drinking Water Act and the California Porter-Cologne Water Quality Act.

Although not directly legally applicable to surface water discharge, drinking water ALs are used by the RWQCB as action-specific, non-promulgated limits for organic contaminants in wastewater discharge. The RWQCB frequently specifies in NPDES permits that groundwater treatment system discharges must meet ALs if wastewater is discharged to a storm drain or flood channel. NPDES permits are required by the federal CWA for certain offsite wastewater discharges and, although a permit is not required for an onsite CERCLA response action, onsite discharge should comply with substantive discharge criteria. Discharge criteria are usually based on the Basin Plan, treatment technology limitations, and case-by-case conditions. The RWQCB incorporates ALs as part of its case-by-case conditions.

Similarly, the Office of Environmental Health Hazard Assessment (OEHHA), in accordance with Health and Safety Code, Section 116365 (California Safe Drinking Water Act of 1996), has adopted Public Health Goals (PHGs) for approximately 46 chemicals. PHGs represent non-mandatory goals based solely on public health considerations and are developed based on best available data in the scientific

literature. These documents provide technical assistance to the Department of Health Services for establishing primary drinking water standards (MCLs) which also consider economic factors and technical feasibility.

3.3.2 Federal Guidance Documents

Many of the procedures and standards to be used in a CERCLA action are set forth in guidance documents issued by EPA. A list of the types of guidance that are TBC is included in the preamble to the NCP, 55 Fed. Reg. 8765 (March 8, 1990). That guidance, along with current updates of and additions to that guidance, is to be considered in this Interim RI/FS and selecting and implementing of the removal action for the Omega site.

3.3.3 Chemical-Specific TBCs

Health Advisories, Drinking Water Exposure Limits (DWELs), California Action Levels (CALs), and California Public Health Goals (PHGs) are potential TBCs for the Omega site. EPA's Office of Drinking Water has developed TBC guidance through their Health Effects Advisories (HEAs) for chemicals that may provide the best available standard for a particular chemical for which no enforceable standard exists. HEAs describe nonpromulgated concentrations of drinking water contaminants at which adverse health effects would not be anticipated to occur over specific exposure durations. HEAs serve as guidance and are not legally enforceable standards. HEAs are developed for 1-day, 10-day, longer term (approximately 7 years), and lifetime exposures, based on noncarcinogenic endpoints of toxicity. HEAs are published in EPA guidance documents. HEAs for certain organic chemicals are listed in EPA's Health Advisories for 25 Organics (March 1987). If EPA determines that MCLs are not protective, the HEAs may be TBCs.

3.4 Other Requirements or Policies

3.4.1 RCRA Manifest Requirements

The preamble to the NCP clarifies that when noncontiguous facilities are treated as one site, activities at the aggregated site, as explained above, must comply with (or waive) substantive requirements of federal or state environmental laws that are ARARs. In addition, the preamble explains that "even where noncontiguous facilities are treated as one site, movement of hazardous waste from one facility to another will be subject to RCRA manifest requirements" (55 Fed. Reg. 8691). As discussed above, hazardous waste generator requirements, including manifest requirements, may be an ARAR for the Omega site.

3.4.2 Offsite Policy

The Procedures for Planning and Implementing Offsite Response Actions (40 CFR Part 300.440) describes the procedures that should be observed when a CERCLA response action involves the offsite storage, treatment, or disposal of CERCLA wastes. The purpose of the offsite policy is to avoid having CERCLA waste contribute to

present or future environmental problems by directing these wastes to facilities determined to be environmentally sound.

3.4.3 Water Rights

Water rights in the Central Basin are adjudicated based on a court judgment. This adjudication resulted in assigning water rights to numerous parties that each hold rights to greater than one percent of the natural safe yield of the basin, and additional parties that each hold rights to less than one percent of the natural safe yield.

The judgment also establishes the duties of a Watermaster, which include annually determining an operating safe yield for the basin, monitoring pumpers' compliance with the judgment, issuing permits for all new and increased pumping in the basin, and preparing an annual report that includes details of pumping activities in the basin. The amount of groundwater that each water rights holder can pump in any year is adjusted by prorating the pumper's prescriptive rights (percentage of natural safe yield) by the operating safe yield, as established by the Watermaster.

The majority of the groundwater pumped from the Central Basin is used for drinking water, supplied to the public by purveyors that are regulated as public water supply systems. Annual pumping may equal or exceed the operating safe yield of the basin. When excess extraction occurs, the judgment has established provisions for assessing pumpers the cost of importing water to replenish the excess amount extracted.

For groundwater cleanup projects, the fee requirement for replenishment water may be waived depending on factors such as the end use of the treated groundwater and results of negotiations or agreements with the Watermaster and parties that have water rights. If the treated groundwater is discharged to surface water which is used for recharge at a downstream location, the replenishment fee could be waived and the discharger would be required to pay only an administrative fee to the Watermaster. If the treated groundwater is discharged to the sewer or treated to drinking water standards and sold to a water purveyor, replenishment water fees may be applicable.

3.5 ARAR Waivers

ARARs can be waived in certain circumstances. The six general waivers stated in CERCLA §121(d) are paraphrased below:

1. The remedial action is an interim measure and is part of a final remedy that will attain the waived ARAR upon completion.
2. Compliance with ARARs will result in greater risk to human health and the environment than other options that do not comply with ARARs.
3. Compliance with ARARs is technically impracticable from an engineering perspective.

4. The remedial action will not meet ARARs, but will attain an equivalent standard of performance through use of another method or approach.
5. The state has not consistently applied a state ARAR or demonstrated the intent to apply the ARAR to similar remedial action sites.
6. Superfund money spent at a site will not provide a balance between the need to protect human health and the environment and the availability of Superfund money for response actions at other facilities.

As appropriate, future reports will document the justification for the waiver of any ARARs.

4

Section
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Section 4

Section 4

Identification and Evaluation of Removal Action Alternatives

The purpose of this section is to develop removal action alternatives based on technologies that are applicable to Site conditions and to evaluate these alternatives independently. The alternatives are then evaluated relative to each other in Section 5. The evaluation of the alternatives is performed in general accordance with the guidelines provided in the USEPA document titled "Guidance on Conducting Non-Time-Critical Removal Actions under CERCLA" (USEPA, August 1993). In addition, portions of the U.S. EPA Guidance for Conducting Remedial Investigations and Feasibility Studies (RI/FS) Under CERCLA (USEPA, October 1988) are also used as appropriate.

4.1 Identification of Removal Alternatives

For the purposes of this EE/CA, three removal action alternatives have been evaluated. These are described below.

4.1.1 Alternative 1: Source Area Contaminant Mass Removal from Groundwater

This alternative provides for groundwater extraction wells in the suspected source area where contaminant concentrations are the highest to maximize removal of contaminant mass. A treatment system would treat extracted groundwater which would then be discharged to surface water/storm drain or sanitary sewer.

Extraction Wells

The hydrogeology of the on-Site upper aquifer limits the amount of groundwater that can be extracted. The upper aquifer in the source area consists of relatively low permeability silt and clay materials, with possible thin interbeds of more permeable material. Information concerning on-Site soil permeabilities and strata distributions has been used to conceptually design the well locations and spacing for this alternative. As shown in Figure 4-1, 14 wells would be installed for groundwater extraction on the southwestern border of the former Omega property. It is anticipated that each well would extract an average flow of approximately 0.3 gpm for a total of approximately 5 gpm. These estimates would be evaluated in the field during design, as appropriate. Operations would be conducted on a pulsed basis to maximize mass removal due to the steep cone of depression that will develop around individual wells in this low permeability material. The basis for the conceptual design for this alternative is given in Appendix D.

Groundwater Treatment

A conceptual design of a groundwater treatment system has been developed for the purpose of evaluating the cost of this and the other two alternatives (i.e., all alternatives require groundwater treatment of extracted water with the same contaminants at different concentrations). The effluent quality for the treatment systems of all three alternatives has been conservatively assumed to be the same – the California Maximum Contaminant Levels (MCLs) for VOCs and the Action Level for 1,4-dioxane (3 ug/L); however, the actual discharge requirements will be determined during the design of the selected alternative and may be different from this assumption. For example, it is recognized that the NPDES discharge limits for some VOCs may be lower than their California MCLs.

For the purpose of evaluating the cost it is assumed that a combination of advanced oxidation process (AOP) which uses hydrogen peroxide and ozone (for 1,4-dioxane and several VOCs) followed by liquid phase granular activated carbon (for other VOCs and Freons) can provide effective treatment of Site contaminants. Also for costing purposes, it has been assumed that the treatment system would be on-Site; however, the actual location of the system will be determined during Remedial Design and may be different and may be located off-Site (e.g., on the Skateland property).

A treatability study would be performed to confirm that an AOP system followed by activated carbon polishing will meet the discharge requirements. Specifically, the study will evaluate the ability of the AOP system to completely oxidize Site contaminants such as Freons, 1,4-dioxane and chlorinated ethenes and will also evaluate the ability of activated carbon to remove contaminants that are not readily oxidized such as chlorinated ethanes. Results of the study will be used to modify the assumed treatment processes if necessary and to provide a technical basis for the design of the groundwater treatment system.

Items that make up the treatment component of all alternatives include:

- Submersible pumps with associated control systems installed in 4-inch extraction wells screened in the upper aquifer
- Sub-grade piping to transfer water from extractions wells to the treatment system
- A treatment building
- An equilibration tank
- An AOP unit that includes hydrogen peroxide and ozone tanks
- Two activated carbon vessels piped in series
- Sub-grade discharge piping

Specifics for Alternative 1 include:

- 14 vertical extraction wells installed to a depth of approximately 100 feet
- 14 1/3 horsepower (hp) submersible pumps with 0.3 - 7 gpm capacity
- A 10-gpm maximum capacity AOP unit
- Two carbon vessels each holding 250 pounds of carbon

Treated Water Discharge

Following treatment, groundwater extracted using this alternative would be discharged under a National Pollutant Discharge Elimination System (NDPES) permit to surface water or the storm drain. A sub-grade pipe would be installed to convey the treated water from the treatment building to the surface discharge point.

4.1.2 Alternative 2: Source Area Hydraulic Containment for Groundwater

This alternative includes groundwater extraction wells along Putnam Street. Pumping from these wells would contain the plume and prevent further migration of contaminants beyond Putnam Street. Extracted groundwater would be treated by a treatment system located on or adjacent to the Omega Site. After treatment, extracted groundwater would be discharged to surface water/storm drain or sanitary sewer. The basis for the conceptual design for this alternative is given in Appendix D.

Extraction Wells

Downgradient of the Site, near Putnam Street, the higher permeability layer of soils that underlie at least a portion of the Site becomes thicker and therefore wells in this layer are capable of producing more water compared to the wells described in Alternative 1. The geometry of the sandy interval will impact the capture zone that would develop under this alternative. Analytical groundwater modeling has been used to provide the basis for a conceptual design for a hydraulic containment system near Putnam Street. This modeling approach assumes that the higher permeability deposits found beneath Putnam Street continue to the Site, which will result in a higher estimated pumping rate. The limited areal extent of the permeable units will in fact decrease the rate of extracted water needed to maintain capture. As shown in Figure 4-2, five wells would be located on the east side of the street and their anticipated capture zones would cover the width of the contaminant plume in this area. Modeling indicates that a total extraction rate of 28 gpm would be sufficient to provide the appropriate capture.

Groundwater Treatment

The groundwater treatment system for this alternative would include those items that were listed in Section 4.3.1 for all alternatives. Specifics for Alternative 2 include:

- Five vertical groundwater extraction wells installed to a depth of approximately 100 feet
- Five 1/3 hp submersible pumps with 0.3 - 7 gpm capacity
- Three new monitoring wells for plume containment verification
- A 35-gpm maximum capacity AOP unit
- Two carbon vessels each holding 500 pounds of carbon

Treated Water Discharge

Following treatment, the extracted groundwater would be discharged under a NDPES permit to surface water, storm drain or sanitary sewer. A sub-grade pipe would be installed to convey the treated water from the treatment building to the discharge point.

4.1.3 Alternative 3: Source Area Hydraulic Containment for Groundwater with Re-injection for Enhanced Anaerobic Biodegradation

This alternative is similar to Alternative 2, with the exception that treated groundwater would be mixed with amendments and re-injected in the source area to stimulate enhanced anaerobic biodegradation (EAB) (Figure 4-3) and expedite the removal of groundwater contaminants in the source area. The basis for the conceptual design for this alternative is given in Appendix D.

Groundwater Treatment

The groundwater treatment system for this alternative would include those items that were listed in Section 4.3.1 for all alternatives. Specifics for Alternative 3 include:

- Five vertical groundwater extraction wells installed to a depth of approximately 100 feet
- Five 1/3 hp submersible pumps with 0.3 - 7 gpm capacity
- Three new monitoring wells for plume containment verification
- A 35-gpm capacity AOP unit
- Two carbon vessels each holding 500 pounds of carbon

EAB

The objective of the EAB component of this alternative is to enhance contaminant removal in the source area by modifying the groundwater conditions to stimulate the

anaerobic biodegradation. This can be achieved by amending the treated groundwater with an electron donor, and re-injecting it on-Site. A more detailed description of this remedial technology is provided in Appendix E.

The primary chlorinated VOCs detected in samples from OW1 (the on-Site well) are PCE, 1,1,1-TCA, TCE, Freon 113, Freon 11, 1,1-DCE, 1,2-DCA, and chloroform. EAB can reduce the contaminant mass in the source area for each of these compounds. Conceptually, the EAB portion of this alternative would consist of the following components:

- A mixing tank where the treatment system effluent is mixed with sodium lactate (an electron donor)
- A chemical pump to transfer lactate from a drum to the mixing tank
- An injection trench
- A transfer pump to convey amended water from the mixing tank through sub-grade piping to the injection trench
- A control panel to allow for programmed re-injection on a pulsed basis

A feature of the Site subsurface that will significantly impact the implementation of EAB is the lack of sufficient higher permeability soils on-Site that would be the targeted for re-injection. Consequently, only a limited amount of amended water could be re-injected on-Site. Groundwater modeling (Appendix D) suggests that only approximately half of the groundwater extracted at Putnam Street (28 gpm) could be re-injected on-Site. Compared with vertical injection wells, an injection trench would improve the ability to inject into the thin, higher permeability layer(s) on-Site. A trench has a higher probability of intersecting the thin discontinuous zones that are capable of transmitting water compared to vertical wells. Injection into the trench would result in a groundwater mound that would locally increase the vertical gradient between the upper and lower aquifer zones. However, the groundwater near the trench would be enhanced with electron donor, so no negative impact on the lower zone is anticipated.

To evaluate the cost, it has been assumed that an injection trench would be used for implementing EAB in this alternative. The results of additional Site characterization sampling that will be performed will be used during Remedial Design to verify if an injection trench is the most effective means for applying EAB amendment. If appropriate, the depth and horizontal dimensions and location of an injection trench would be determined during the design phase; however, for cost estimating purposes a depth of 75 feet has been assumed along with the location shown in Figure 4-3.

It may be possible to combine the installation of the re-injection trench with any excavation that may occur as part of the on-Site soils remedy, resulting in a cost effective remedial action that would target two media of the Site.

Typically, EAB performance is enhanced when the amendment solution is provided on a pulsed basis. For the purpose of costing this alternative, it is assumed that half of the treated groundwater (14 gpm) will be amended and re-injected half of the time and discharged to surface water or sanitary sewer the other half. Therefore, the re-injection assumption combined with the pulse frequency result in an average EAB flow of approximately 7 gpm on an annual basis. Based on CDM experience with EAB systems, we have assumed a target sodium lactate concentration for the feed solution of 3,000 mg/L. Therefore, to evaluate cost it is assumed that an average of approximately 250 pounds of sodium lactate would be used per day. Bench-scale and/or pilot scale testing would be conducted to verify the applicability of EAB and to provide a design basis for the EAB system.

4.2 Evaluation Criteria

The following evaluation criteria have been used to analyze the three removal action alternatives described above for the purpose of identifying a preferred removal action:

- 1) Effectiveness
 - a) Overall protection of human health and the environment
 - b) Compliance with ARARs
 - c) Long-term effectiveness and permanence
 - d) Reduction of toxicity, mobility, or volume through treatment
 - e) Short-term effectiveness
- 2) Implementability
- 3) Cost

Each of the above criteria is described below:

- Overall Protection of Human Health and the Environment -- This criterion determines whether the alternatives can adequately protect human health and the environment, in both the short-term and long-term, from unacceptable risks posed by contaminants present at the Site by eliminating, reducing, or controlling exposures to levels which would meet the removal action objectives. This criterion is based on a composite of other factors assessed under the evaluation criteria, especially, long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs, which are described below. It addresses specifically how each removal action alternative achieves protection over time, and how site risks are reduced.

- Compliance with Applicable or Relevant and Appropriate Requirements (ARARs) - This criterion evaluates how each alternative complies with ARARs identified for the Site in Section 3.2. Evaluation of alternatives by this criterion relies on action-specific ARARs for the removal action alternative based on the technologies used to meet the removal action.
- Long-term Effectiveness and Permanence -- This evaluation criterion addresses the results of a removal action in terms of the risk remaining at the Site after removal action objectives have been met. The primary focus of this evaluation is the extent and effectiveness of the controls that may be required to manage the risk posed by treatment residuals and/or untreated wastes within the scope of the removal action. The following components of this criterion are considered for each alternative:
 - Magnitude of remaining risk after cleanup
 - Adequacy of controls
 - Reliability of controls
- Short-Term Effectiveness -- This evaluation criterion addresses effects of the removal action during the construction and implementation phase until the removal action objectives are met. Under this criterion, alternatives are evaluated with respect to their effects on human health and the environment during implementation of the removal action. The following factors of this criterion are considered for each alternative:
 - Protection of community health during the removal actions
 - Protection of workers' health during the removal actions
 - Time until removal action objectives are achieved
 - Environmental impacts (adverse impacts to the environment as a result of removal activity and reliability of mitigation measures in preventing or reducing the potential impacts)
- Reduction of Toxicity, Mobility, or Volume -- This evaluation criterion addresses the effectiveness of the removal action in reducing the toxicity, mobility, or the volume of hazardous substances left at a site. This criterion is satisfied when treatment is used to reduce the principal threats at a site through destruction of toxic contaminants, reduction of the total mass of toxic contaminants, irreversible reduction in contaminant mobility, or reduction of the total volume of contaminated media. The following factors of this criterion are considered for each alternative:
 - The treatment or recycling processes to be used, and materials to be treated

- The amount of hazardous materials to be treated or recycled
 - The estimated degree of expected reduction in toxicity, mobility, or volume
 - The degree to which the treatment is irreversible
 - The type and quantity of treatment residuals expected to remain after treatment
 - Whether the alternative satisfies the preference for treatment
- Implementability -- The implementability criterion addresses the technical and administrative feasibility of implementing a removal action alternative and the availability of various services and materials required during its implementation. This criterion involves analysis of the following factors:
- Technical feasibility, with regards to feasibility of construction and operation of the alternative, adaptation of the alternative to the environmental conditions at the site, the reliability of the technologies composing the alternative, the ease of undertaking additional removal action (if any), and the ability to monitor the effectiveness of the remedy.
 - Administrative feasibility, such as operating permits/approvals, ability to implement institutional controls, etc.
 - Availability of services and materials, including the availability of personnel and technology; off-site treatment, storage and disposal capacity and services; and availability of necessary services, equipment, materials and specialists.
- Cost -- The cost criterion evaluates removal action alternatives based on economic considerations, which primarily consist of cost estimates derived for each alternative. The cost estimates are usually composed of capital cost and annual (O&M) cost. The costs for each alternative are estimates and their accuracy may be within a -30 percent to +50 percent of the final project cost.

The estimates of capital cost for each alternative consists of direct (construction) and indirect (non-construction and overhead) cost. Direct cost includes expenditures for the equipment, labor, and materials necessary to perform removal actions. Capital cost for each removal alternative was derived from literature sources, vendor quotes, and previous studies. Indirect costs include engineering expenses such as engineering design, construction supervision, permit and related expenses, contingency allowances, and other services that are not part of the actual removal activities but are required to complete the removal action.

Annual costs (O&M costs) are the costs necessary to ensure the continued effectiveness of the removal action. Annual costs include operating labor costs,

maintenance expenses, auxiliary materials and utilities, disposal of any residuals, and monitoring/support costs.

4.3 Evaluation of Alternatives

The definitions of the evaluation criteria described above have been used to evaluate each alternative independently (i.e., not relative to each other – this is done in Section 5).

4.3.1 Alternative 1: Source Area Contaminant Removal From Groundwater

Effectiveness

Overall protection of human health and the environment

This alternative is protective of the environment in that contaminant mass is removed from groundwater on-Site, thereby limiting migration of contaminants to downgradient areas. However, because extraction wells are placed to maximize contaminant removal from the source area (and not overall contaminant capture), continued, but limited, migration of contaminants to downgradient areas would continue.

Compliance with ARARs

This alternative would comply with the Site ARARs, in particular the action-specific ARARs that apply to construction and operation of the groundwater treatment system. Specifically, the extracted groundwater would be treated to the standards established in a NPDES permit that would be issued in accordance with the objective set forth in the Basin Plan (see Section 3.2).

Long-term effectiveness and permanence

While significant contaminant mass would be removed from Site groundwater under this alternative, some contaminant mass would remain on-Site largely due low permeability soils that limit contaminant mass removal. Also, treatment of the groundwater would produce residuals in the form of spent activated carbon; however, the spent carbon would be transported to an off-Site regeneration facility and the associated risk would be very low.

Reduction of toxicity, mobility, or volume through treatment

This alternative results in the removal of contaminants from Site groundwater via destruction (AOP unit) and transfer to another medium (activated carbon). Contaminant mobility is reduced because mass removal and hydraulic control of the source.

Short-term effectiveness

There would be an increase in short-term risk associated with construction of the extraction wells, piping and groundwater treatment system. However, these risks are typically mitigated by using common construction safety procedures and construction

oversight. RAOs may not be met after groundwater extraction begins because capture of the entire plume within the Phase 1a area may not be achieved.

Implementability

This alternative is considered technically feasible in that it utilizes treatment units that are proven and easily constructed using standard construction practices. A treatability study would be conducted to verify that an AOP system followed by activated carbon treatment would be sufficient to meet all discharge requirements. Some administrative tasks include obtaining a NPDES permit for surface discharge of treated groundwater and access agreements for installation of extraction wells and construction of the treatment system and the discharge piping.

Cost

Cost estimates have been performed for each of the removal action alternatives based on a conceptual level design of each alternative. The costs were estimated at a feasibility study level of +50 percent to -30 percent. The cost estimates for Alternative 1 are as follows:

Capital Costs: \$3,539,000
Annual Costs: \$329,000
Total Present Worth Cost: \$7,622,000

Major costing assumptions:

- Treatment of extracted groundwater can be achieved to the necessary levels using an AOP system followed by activated carbon polishing.
- The average flow of extracted groundwater is 5 gpm.
- 14 vertical extraction wells would be installed to a depth of approximately 100 feet
- The system would operate for a period of 30 years
- The discount rate is 7 percent

4.3.2 Alternative 2: Source Area Hydraulic Containment For Groundwater

Effectiveness

Overall protection of human health and the environment

This alternative is protective of the environment in that the plume is controlled and prevented from migration to areas downgradient of Putnam Street. This alternative provides some protection to human health by removing contaminant mass from groundwater.

Compliance with ARARs

This alternative would comply with the Site ARARs, in particular the action-specific ARARs that apply to construction and operation of the groundwater treatment system. Specifically, the treated water would be treated to the standards established in a NPDES permit, which would be prepared in accordance with the objective set forth in the Basin Plan (see Section 3.2).

Long-term effectiveness and permanence

The groundwater extraction system would remove contaminant mass from the groundwater and would reduce contaminant concentrations. It is expected that contaminant mass would remain on Site largely due to the low permeability of the materials in the source area. Like Alternative 1, this alternative would produce treatment residuals in the form of spent activated carbon. The spent carbon would be transported to an off Site regeneration facility and the associated risk would be very low.

Reduction of toxicity, mobility, or volume through treatment

Using this alternative, chlorinated ethenes and 1,4-dioxane would be removed from the extracted groundwater by destruction (AOP unit) and other contaminants would be transferred to another medium (activated carbon). In addition, contaminant mobility across Putnam Street is prevented because of the hydraulic containment system.

Short-term effectiveness

There would be an increase in short-term risk due to implementation of this alternative associated with construction of the extraction wells, piping and groundwater treatment system. Unlike Alternative 1, construction activities would be required off-Site to install extraction wells and sub-grade piping. However, these risks are easily mitigated through use of common construction safety procedures and construction oversight. RAOs would be met soon after groundwater extraction begins when hydraulic containment is established.

Implementability

This alternative is technically feasible because it utilizes treatment units that are proven and easily constructed using standard construction practices. A treatability study would be conducted to verify that an AOP system followed by activated carbon treatment would be sufficient to meet all discharge requirements. Some administrative tasks include obtaining a NPDES permit for surface discharge of treated groundwater and potentially addressing access issues for construction of the extraction and monitoring wells and sub-grade piping.

Cost

The cost estimate for Alternative 2 is as follows:

Capital Costs: \$2,773,000

Annual Costs: \$296,000

Total Present Worth Cost: \$6,447,000

Major costing assumptions:

- Treatment of extracted groundwater can be achieved to the necessary levels using an AOP system followed by activated carbon polishing.
- The average extraction flow necessary to maintain hydraulic containment of the plume at Putnam Street is 28 gpm.
- Five vertical extraction wells would be installed to a depth of approximately 100 feet
- The system would operate for a period of 30 years
- The discount rate is 7 percent

4.3.3 Alternative 3: Source Area Hydraulic Containment For Groundwater, with Re-injection for Enhanced Anaerobic Biodegradation

Effectiveness

Overall protection of human health and the environment

This alternative is protective of the environment in that contaminant mass is removed from groundwater using two concurrent technologies: groundwater extraction at Putnam Street and EAB by re-injection on Site. The use of EAB will increase the rate of mass removal from on-Site low permeability materials. Therefore, this alternative is expected to expedite the mass removal rate. Further the dual action of the hydraulic containment and the EAB would prevent the migration of contaminant downgradient of Putnam Street. This alternative provides some protection to human health by removing contaminant mass from groundwater.

Compliance with ARARs

This alternative would comply with the Site ARARs, in particular the action-specific ARARs that apply to construction and operation of the groundwater treatment system and for the EAB. Specifically, the treated water would meet the standards established in a NPDES permit prepared in accordance with the objective set forth in the Basin Plan (see Section 3.2). Re-injected groundwater would also be treated to the appropriate levels according to ARARs related to re-injection for the purpose of in situ treatment.

Long-term effectiveness and permanence

While significant contaminant mass would be removed from groundwater under this alternative, some contaminant mass is expected to remain on-Site largely due to diffusion limited transport of contaminants from within lower permeability soils in the source area. Like Alternatives 1 and 2, this alternative would produce treatment residuals in the form of spent activated carbon. The spent carbon would be transported to an off-Site regeneration facility and the associated risk would be very low.

Reduction of toxicity, mobility, or volume through treatment

This alternative results in the removal of certain contaminants from groundwater via destruction (AOP unit), transfer of others to another medium (carbon), and *in situ* degradation of contaminants via EAB. In addition, the dual action of the hydraulic containment and the EAB would prevent the migration of contaminant downgradient of Putnam Street.

Short-term effectiveness

There would be an increase in short-term risk due to implementation of this alternative associated with construction of the extraction wells, piping, re-injection trench, and the groundwater treatment system. Unlike Alternative 1, construction activities would be required off-Site to install the extraction wells and the sub-grade piping. However, these risks are easily mitigated through use of common construction safety procedures and construction oversight. RAOs would begin to be met soon after groundwater extraction and EAB begin when hydraulic containment is established.

Implementability

This alternative is technically feasible because it utilizes treatment units that are proven and easily constructed using standard construction practices. A treatability study would be conducted to verify that an AOP system and subsequent activated carbon treatment would be sufficient to meet all discharge requirements. Installation of the re-injection trench would require relatively specialized equipment – an excavator capable of reaching approximately 75 feet bgs. However, this equipment is available and this part of the alternative would be constructed on-Site, thereby reducing impacts to off-Site activities. Other than the re-injection component, the EAB element of this alternative does not pose significant implementability issues. This technology has been successfully implemented across the country for similar applications. Bench- and/or pilot-scale testing would be performed to verify the effectiveness of EAB for Site conditions.

Some administrative tasks include obtaining a NPDES permit for surface discharge and for re-injection of treated groundwater and potentially addressing access issues for construction of the extraction and monitoring wells, the sub-grade piping, and the re-injection trench.

Cost

The cost estimate for Alternative 3 is as follows:

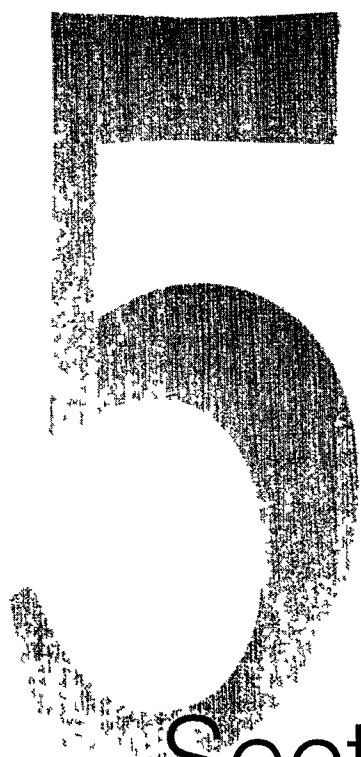
Capital Costs: \$3,948,000

Annual Costs: \$482,000

Total Present Worth Cost: \$9,055,000

Major costing assumptions:

- The AOP system followed by activated carbon polishing would meet discharge requirements
- The average extraction flow necessary to maintain hydraulic containment of the plume at Putnam Street is 28 gpm
- The re-injection trench will be built to a depth of 75 bgs and a length of approximately 100 feet
- All of the excavated soils during trench construction will be disposed off-Site as non-hazardous waste
- The average re-injection rate for EAB is 7 gpm
- The average sodium lactate use rate is 250 pounds per day
- The system would operate for a period of 20 years
- The discount rate is 7 percent



Section Five

Section 5

Comparative Analysis of Removal Action Alternatives

This section compares the *relative* performance of the alternatives regarding the evaluation criteria and forms the basis for recommending one of the alternatives.

5.1 Effectiveness

Overall protection of human health and the environment

Of the three alternatives, Alternative 3 provides the highest overall protection of human health and the environment. Alternative 3 optimizes mass removal rate by the coupled effect of the groundwater extraction system at Putnam Street and the EAB.

Using the same reasoning, Alternative 2 would be protective of both human health and the environment because it minimizes further downgradient transport of contaminants beyond Putnam Street.

Compliance with ARARs

All three alternatives rate similarly with respect to this criterion. Alternatives 1 and 2 are very similar in this regard, as ARARs are mainly associated with the treatment of groundwater. Alternative 3 has additional ARARs associated with re-injection to enhance in situ treatment; however, no problems are anticipated in complying with these additional ARARs.

Long-term effectiveness and permanence

Using the same reasoning provided under the overall protection criterion, of the three alternatives, Alternative 3 would result in the smallest residual contaminant mass. Alternative 1 may have a higher *initial* mass removal rate, but it allows remaining mass to migrate downgradient of the Site and Alternative 3 would have the highest overall mass removal rate. Alternative 2 may remove less contaminant mass than Alternative 1, but provides better containment of the plume than Alternative 1 and prevents migration of the plume downgradient of Putnam Street.

All three alternatives would produce treatment residuals in the form of spent activated carbon. In all three cases the carbon would be transported and regenerated off-Site, therefore the risk associated with this residual waste would be similar, differing only in the amount of spent carbon generated. The amount of spent carbon generated would be proportional to the amount of groundwater treated; therefore Alternatives 2 and 3 (28 gpm) would produce similar amounts that would be greater than that for Alternative 1 (~5 gpm).

Reduction of toxicity, mobility, or volume through treatment

All three alternatives incorporate treatment of Site contaminants via *ex situ* groundwater treatment using AOP and activated carbon. Alternative 3 has the highest degree of reduction of toxicity, mobility or volume through treatment because it incorporates *ex situ* treatment of groundwater, *in situ* treatment of groundwater (EAB) and hydraulic containment to reduce contaminant mobility. Alternative 2 has the next highest reduction since it combines *ex situ* groundwater treatment with hydraulic containment.

Short-term effectiveness

All three alternatives include construction work and the associated short-term environmental impacts; however, in all cases these impacts are readily mitigated using standard construction safety protocols. Alternative 3 has a lower short-term effectiveness rating in that it includes installation of a re-injection trench that would require disposal of a significant volume of contaminated soil. However, this removal of soils coupled with the *in situ* treatment of groundwater via EAB would result in a higher degree of long-term effectiveness for this alternative.

5.2 Implementability

Technical Feasibility

All three alternatives have similar components that have similar degrees of technical feasibility. Specifically, the groundwater extraction and treatment elements of the alternatives are proven technologies with many examples of successful implementations at sites with similar conditions. A treatability study will be performed to verify that the treatment processes will meet discharge requirements. The EAB component reduces the rating of Alternative 3 for this criterion relative to the other alternatives because of the installation of the 75-foot re-injection trench, the uncertainty of injection rate into this trench, and the challenge of delivering the EAB amendments to the targeted area of the aquifer.

Administrative Feasibility

The re-injection/EAB component reduces the rating of Alternative 3 for this criterion slightly lower relative to the other two alternatives. An injection permit would be required and monitoring would need to be performed to comply with this permit. However, these additional administrative requirements are not anticipated to impede the implementation of this alternative.

5.3 Cost

Table 5-1 shows a summary of the cost estimates for the three removal action alternatives.

For the present worth calculation it has been assumed that Alternatives 1 and 2 would operate for 30 years, while the EAB component of Alternative 3 would allow a shorter operation period of 20 years.



Section Six

Section 6

Recommendation of Removal Action Alternative

This section gives the rationale for selecting the recommended removal action alternative.

Table 6-1 presents a summary of the evaluation of removal action alternatives using the criteria described in Sections 4 and 5.

Compared to Alternative 1, Alternatives 2 and 3 have significantly higher ratings for reduction of contaminant mobility and overall protection of human health and the environment due to their ability to provide superior contaminant migration control downgradient of the Site. Additionally, Alternative 3 provides greater contaminant mass destruction via treatment when compared to Alternatives 1 and 2.

Although contaminant mass removal is not a RAO, Alternative 3 offers additional benefits by reducing contaminant mass up gradient of the containment system. Alternative 3 rates lower for some other evaluation criteria (e.g., higher cost and lower short term effectiveness due to risks associated with construction) because of implementation issues regarding re-injection of treated groundwater for EAB. However, the additional efforts and cost associated with this aspect of Alternative 3 are justified by the additional benefits it provides. This is the basis for selecting Alternative 3 as the recommended alternative.



Section Seven

Section 7

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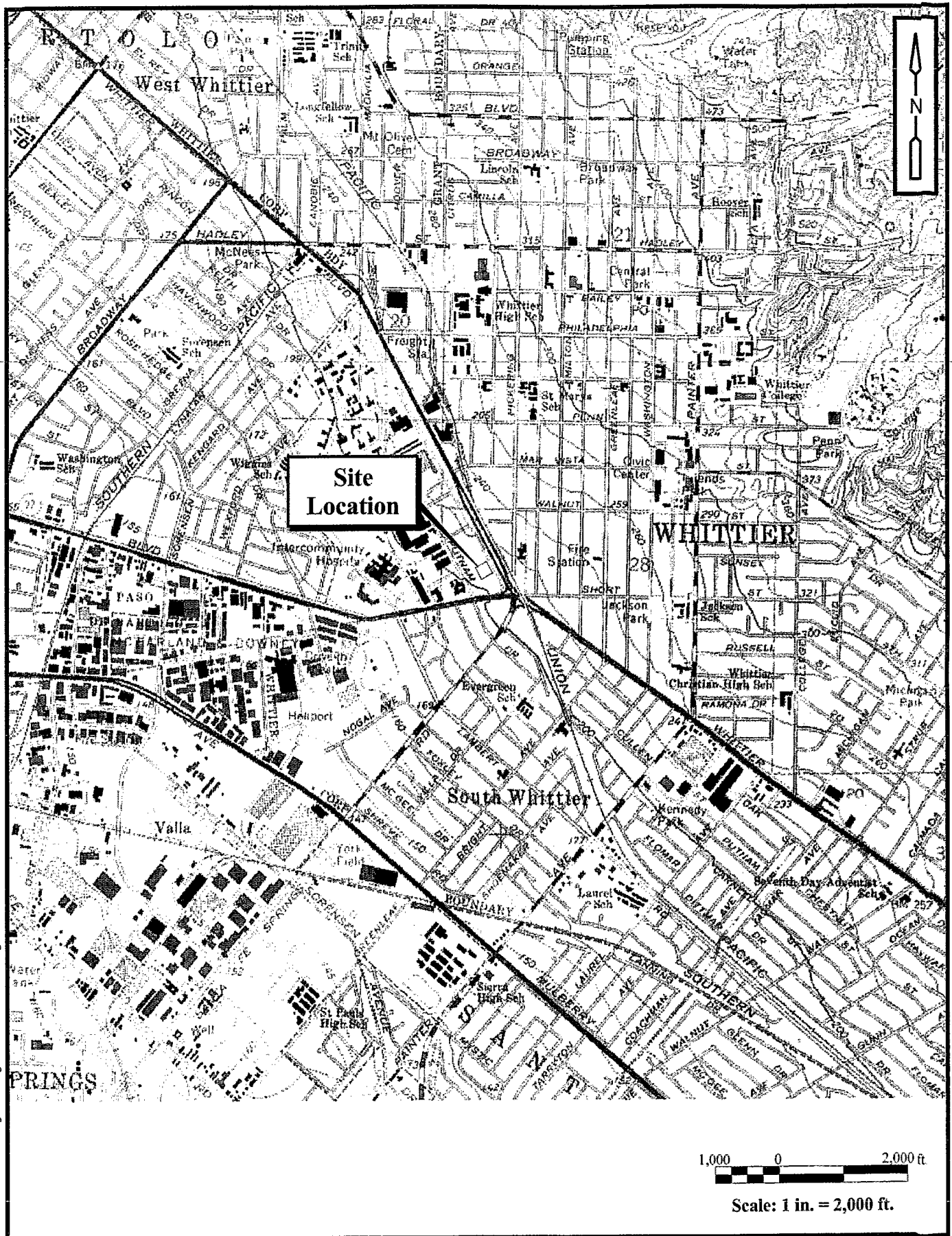
Section Eight

Section 8

Section 8

Figures

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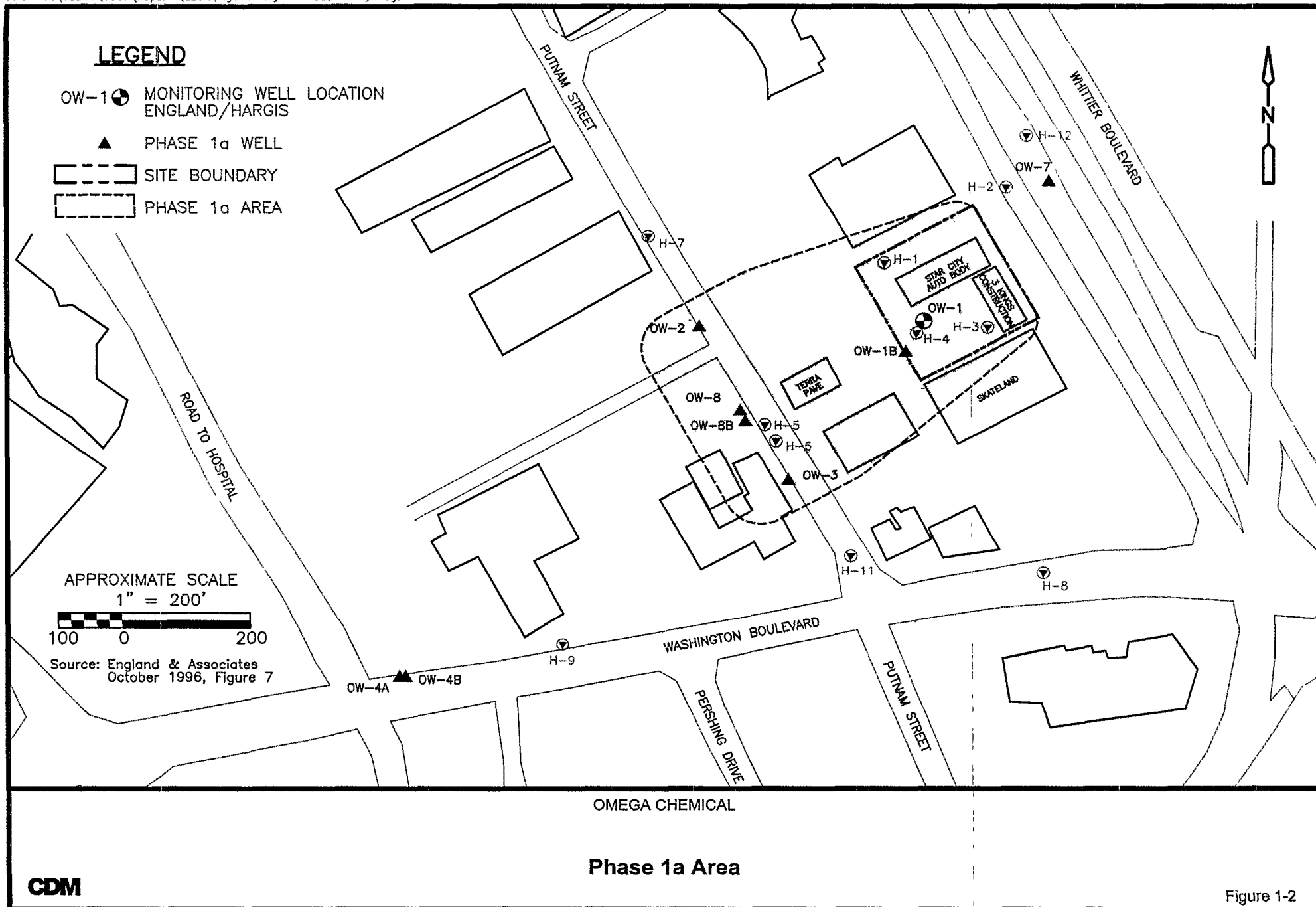


OMEGA CHEMICAL

Site Location Map

CDM

Figure 1-1



LEGEND

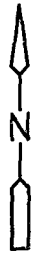
● GROUNDWATER EXTRACTION WELL

--- SITE BOUNDARY

[] PHASE 1a AREA

NOTE

ALL LOCATIONS ARE APPROXIMATE.



1" = 100'
50 0 100



OMEGA CHEMICAL

Removal Action Alternative 1

CDM

Figure 4.1

LEGEND

● GROUNDWATER EXTRACTION WELL

--- SITE BOUNDARY

[] PHASE 1a AREA

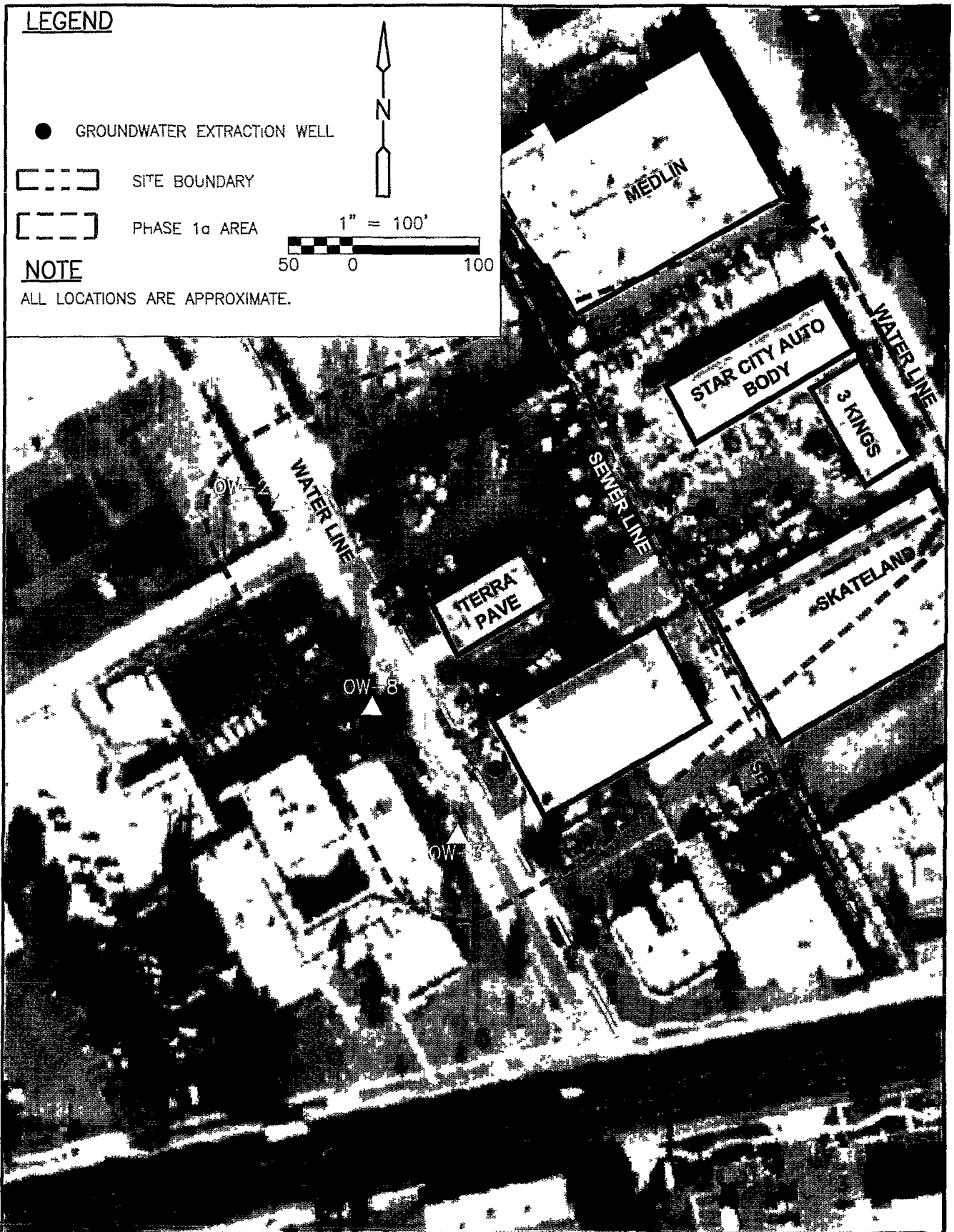


1" = 100'

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NOTE

ALL LOCATIONS ARE APPROXIMATE.



OMEGA CHEMICAL

Removal Action Alternative 2

CDM

Figure 4.2

LEGEND

● GROUNDWATER EXTRACTION WELL

--- SITE BOUNDARY

--- PHASE 1a AREA

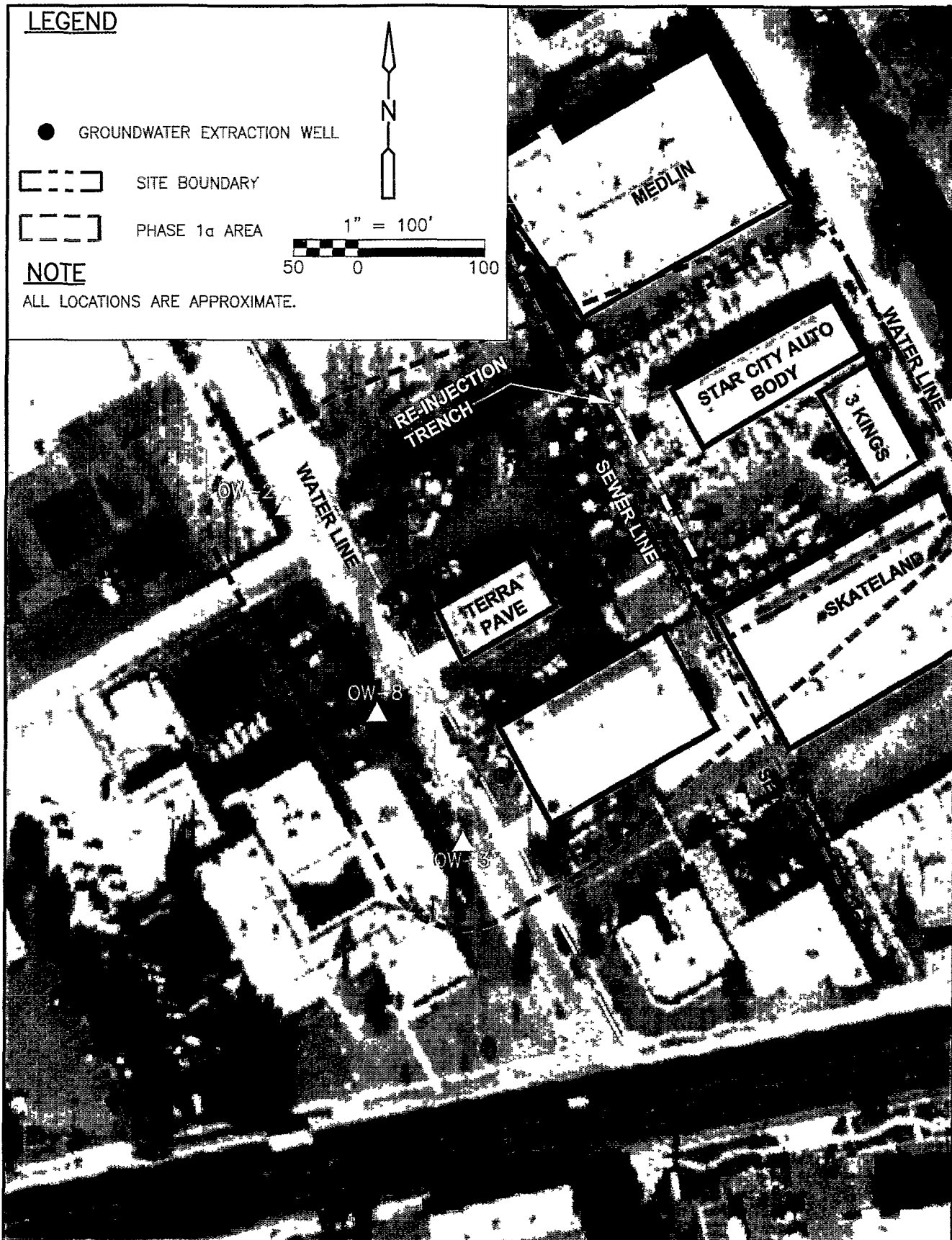


1" = 100'

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NOTE

ALL LOCATIONS ARE APPROXIMATE.



OMEGA CHEMICAL

Removal Action Alternative 3

CDM

Figure 4.3

9

Section
Nine

Section 9

Section 9 Tables

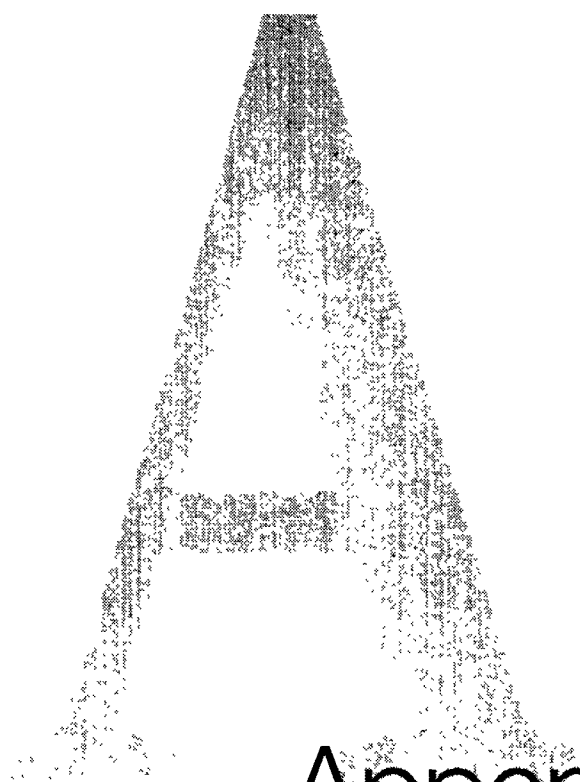
Table 5-1
Summary of Cost Estimates

Alternative	Capital Cost	Annual Cost	Present Worth
1	\$3,539,000	\$329,000	\$7,622,000
2	\$2,773,000	\$296,000	\$6,447,000
3	\$3,948,000	\$482,000	\$9,055,000

Table 6-1
Summary of Alternatives Evaluation

Criterion	Alternative 1	Alternative 2	Alternative 3
Overall Protection	Low	Moderate	High
Compliance with ARARs	High	High	High
Long-Term Effectiveness	Low	Moderate	High
Treatment	Low	Moderate	High
Short-Term Effectiveness	Moderate	High	Moderate
Technical Implementability	High	High	Moderate
Admin. Implementability	High	High	Moderate
Cost ¹	Moderate	High	Low

¹ A high rating for cost means a relatively low overall cost.



Appendix A

Appendix A

Miscellaneous Figures and Tables

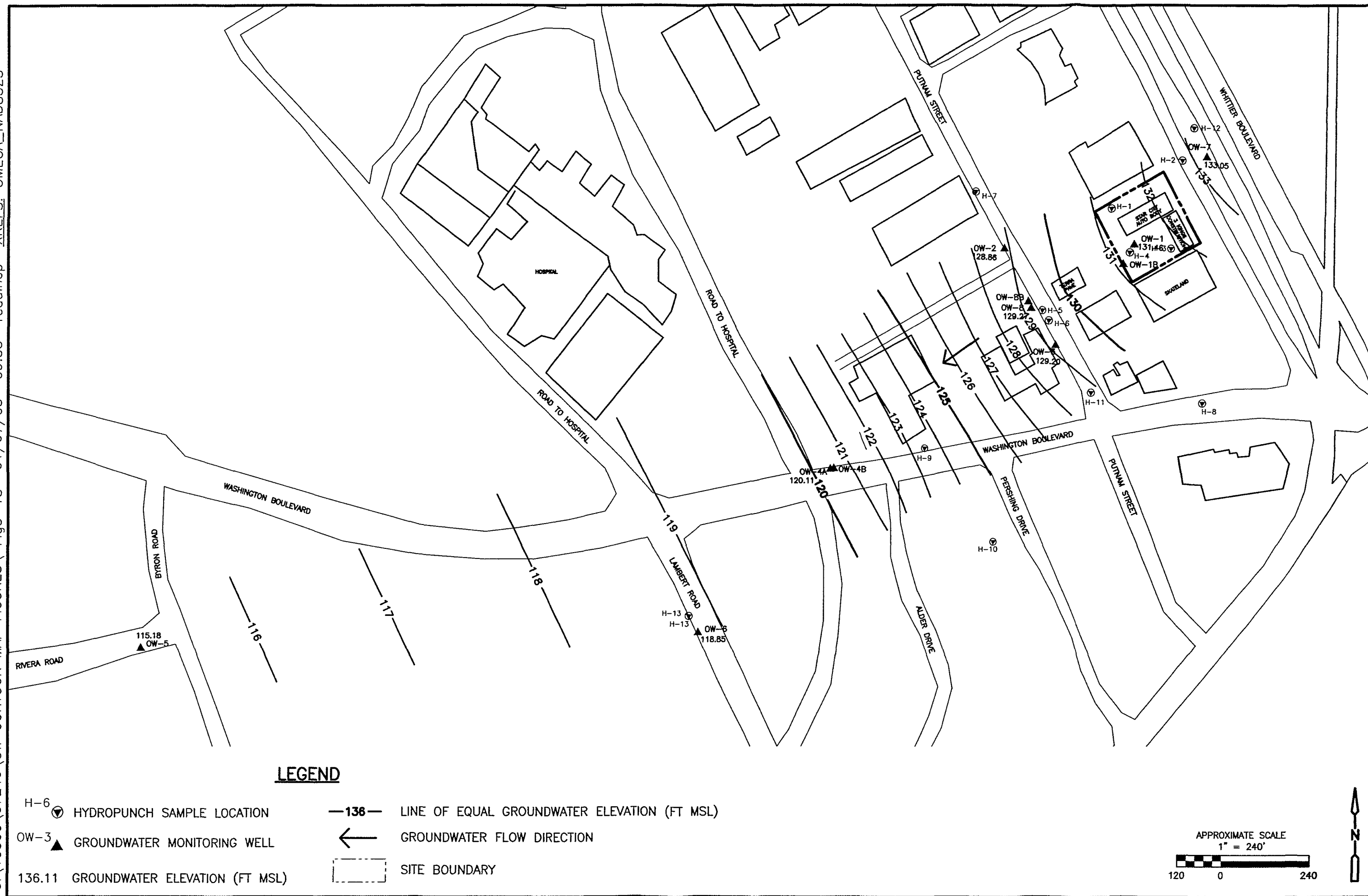


Figure 3-18
Groundwater Elevation Contour Map
August 2004

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Figure 3-21
Omega Site Phase 1a Area
Well and Cross-Section Locations

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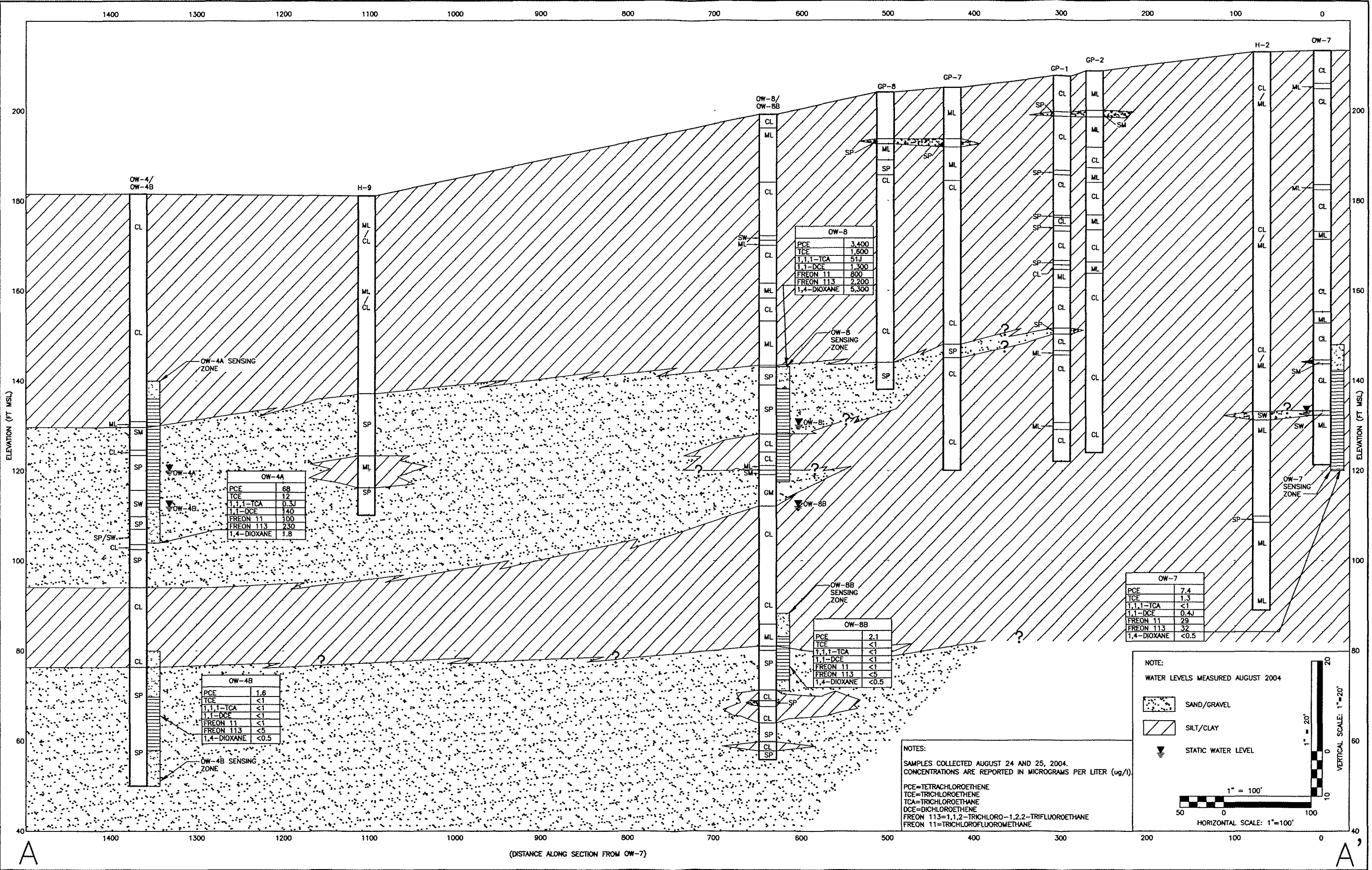


Figure 3-22
Omega Site Cross-Section A-A'

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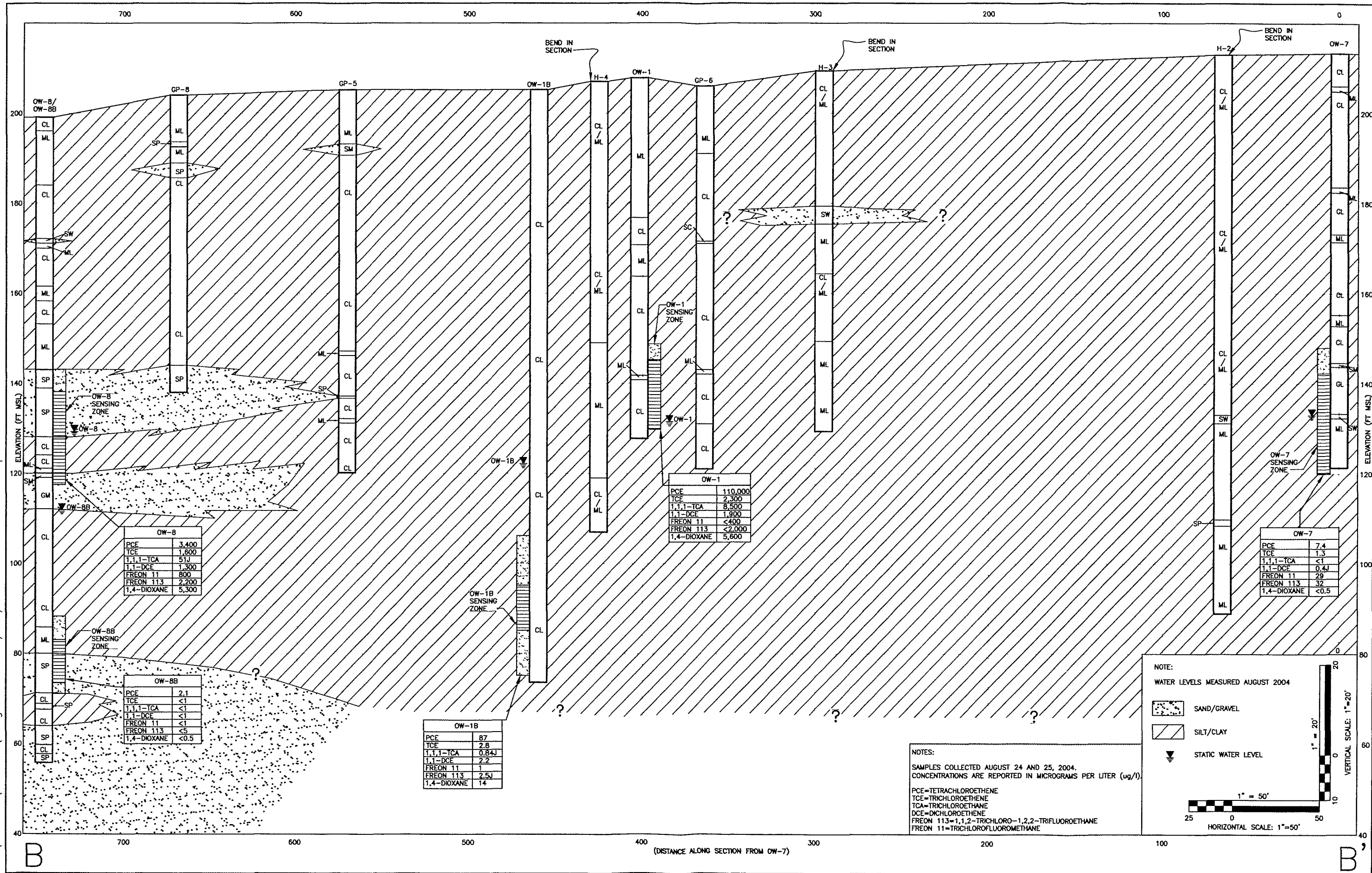


Figure 3-23
Omega Site Cross-Section B-B'

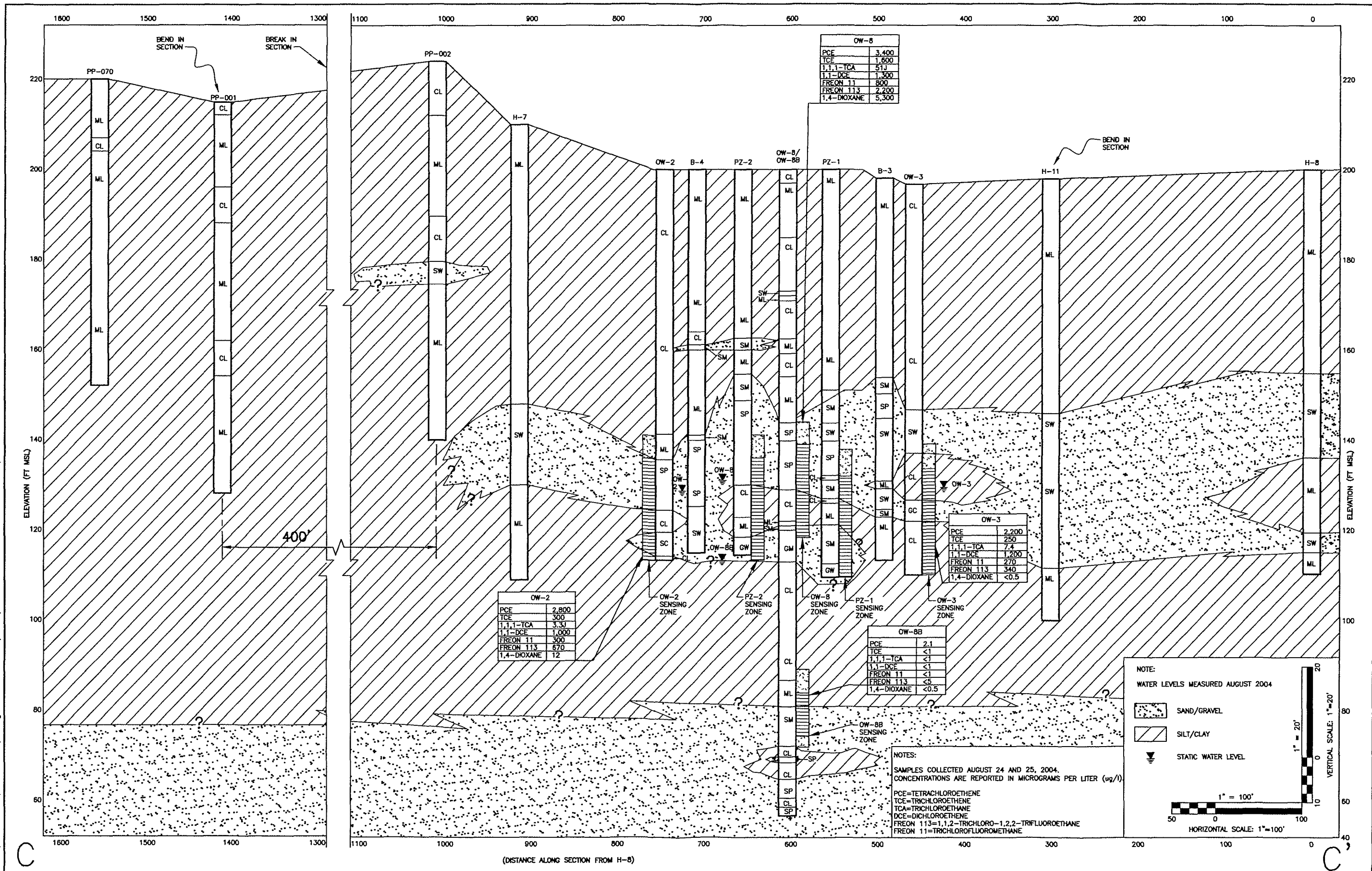
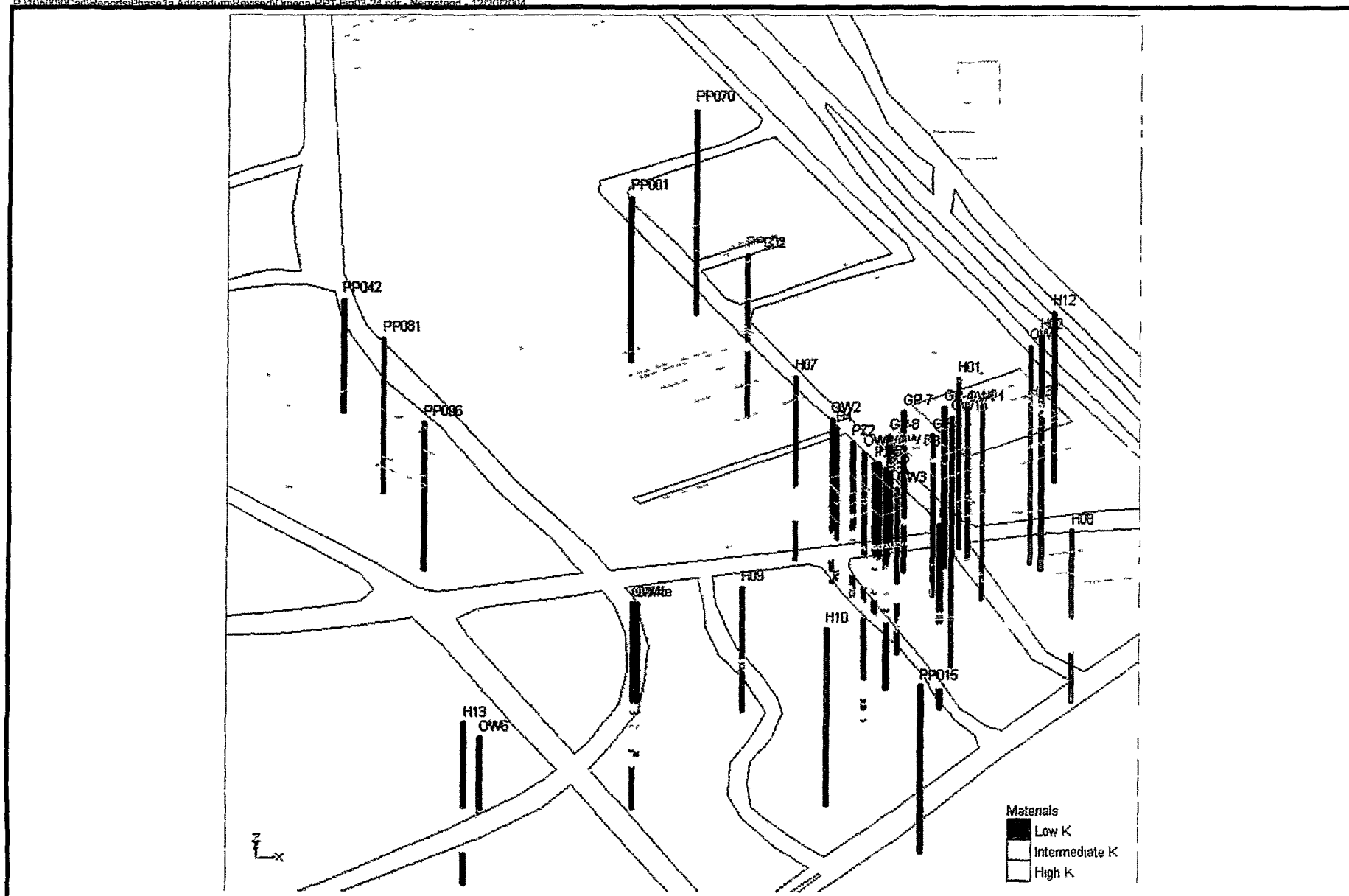
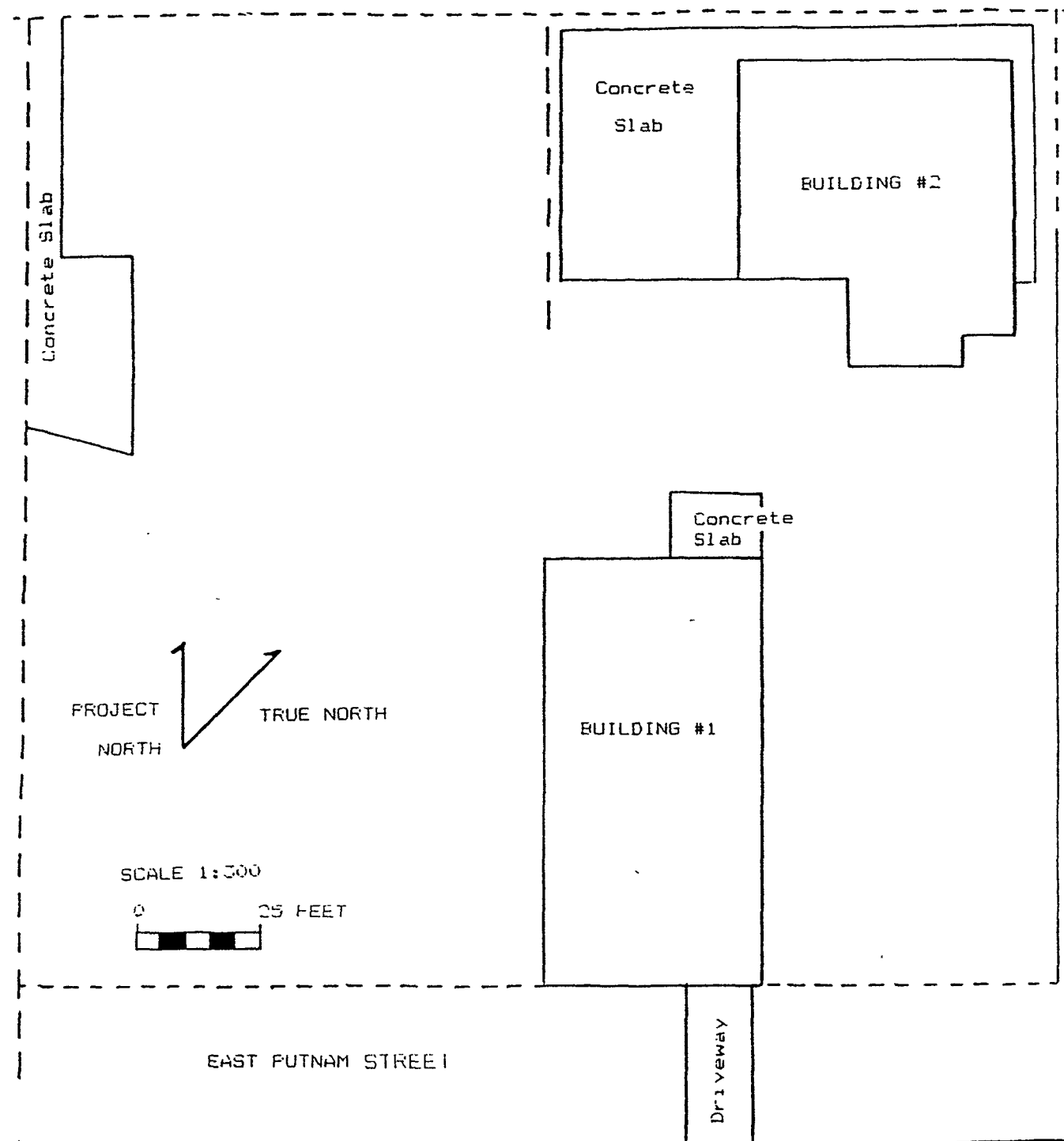


Figure 3-24
 Omega Site Cross-Section C-C'

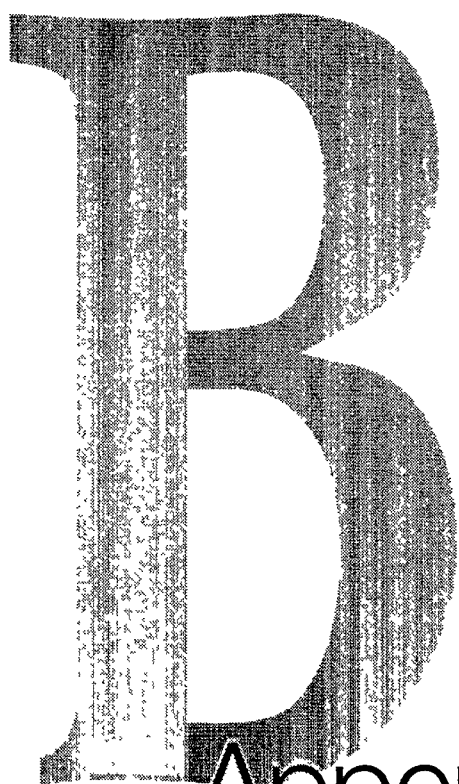


OMEGA CHEMICAL

Three-Dimensional View of Lithology



CARDINAL ENVIRONMENTAL CONSULTANTS INC.
FIGURE 4 - PLOT PLAN
NELCO
12511 EAST PUTNAM STREET
WHITTIER, CALIFORNIA
AUGUST, 1991



Appendix B

Appendix B

Stepwise Human Health Risk Ratio Calculations

Appendix B

Stepwise Human Health Risk Ratio Calculations

As discussed in Section 2.4, groundwater within the contaminant area (Gage aquifer) is currently not used for domestic, industrial, or agricultural purposes. Use for potable purposes within this area is also unlikely for the future due to the presence of high concentrations of total dissolved solids (TDS). No evidence suggests that contamination extends to any potable aquifer that underlies the Gage aquifer. If future data collection indicates that vertical migration has occurred, then future risk evaluations will need to address a potential drinking water pathway.

In this appendix section, although ingestion of groundwater is not a completed pathway, a stepwise human health risk ratio evaluation based on this hypothetical exposure pathway was conducted to provide Site management with additional information regarding the magnitude of existing contamination at the Site.

At the Omega Site, risks from contaminated groundwater could theoretically result from volatilization of groundwater contaminants and subsequent intrusion of vapors into indoor spaces. In order to completely evaluate the pathway for volatilization of groundwater contaminants and subsequent intrusion of vapors into indoor spaces, exposure to soil gas should be evaluated simultaneously. Quantification of both soil gas and groundwater risks is a way of evaluating which contamination source provides the greatest health threat. Therefore, this groundwater pathway will be evaluated in the separate risk assessment to be prepared for the On-Site Soils RI/FS.

The On-Site Soil RI/FS risk assessment will include an evaluation of the soil gas results at the Site. Therefore, this stepwise risk evaluation does not address risks associated with soil and soil gas. Because the Omega facility is located in an urban area that has been developed for decades, provides no suitable habitat, and contaminated soils are covered with buildings, asphalt, or concrete, ecological impacts from the facility are not expected and are not evaluated.

The following documents and others cited within this section form the basis for this stepwise risk evaluation:

- Correspondence from Chris Lichens, EPA Region 9 Superfund Project Manager, to Chuck McLaughlin, OPOG Project Coordinator of de Maximis Inc., on March 18, 2005.
- Guidance on Conducting Non-Time Critical Removals Under CERCLA. EPA, Office of Emergency and Remedial Response. EPA 540-R-93-057, PB93-963402, August 1993.
- User's Guide and Background Technical Document for USEPA Region 9's Preliminary Remediation Goals (PRG) Table. EPA. 2004.

- Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A). Interim Final. EPA/5401/1-891002. December 1989.

Per the EPA guidance letter, this appendix provides the following evaluations:

- Comparison of groundwater chemical concentrations in Phase 1a Area wells to MCLs (Federal and State of California) and to current Region 9 Tap Water PRGs
- Cumulative human health risks and hazards for chemicals in groundwater in the Phase 1a Area using the Region 9 stepwise risk ratio approach
- Plots of cumulative risks and hazards for Phase 1a wells.

B.1 Identification of Chemicals of Potential Concern

Selection of COPCs is based on toxicity screening or an analysis of each chemical's potential to contribute to site-related risks. Toxicity screening is conducted by comparing maximum detected concentrations of chemicals detected in a medium with generic risk-based concentrations for the medium. This approach is conservative and will result in inclusion rather than exclusion of chemicals from quantitative risk analyses. Not all of the selected chemicals will, therefore, necessarily be associated with risk. COPCs will only include chemicals detected in large enough concentrations and distributed widely enough in Site media to present a potential human health hazard.

Groundwater investigations were performed by a variety of consultants to Omega between 1985 and 2005. Only the results for the more recent groundwater sampling events (1996 to 2005) have been entered into a database. Because groundwater concentrations vary widely over time, only groundwater data from 2004 and 2005 were used to represent current conditions in this evaluation. Summary statistics for the 2004-2005 groundwater data used in this evaluation are provided in Table B-1.

B.1.1 EPA and CalEPA Maximum Contaminant Levels

To identify COPCs for groundwater, detected chemical concentrations at the Site were compared to maximum contaminant limits (MCLs) and chemical concentrations in groundwater that are protective of indoor air. Although use of groundwater as a source of drinking water is not considered a plausible scenario within the containment zone (and hence, MCLs may not be pertinent to the remediation of the groundwater), chemicals exceeding their MCL are not eliminated as COPCs. However, chemicals that exceeded MCLs but did not not exceed concentrations in groundwater that are protective of indoor air are not included as COPCs for evaluation of potential air pathways (vapor intrusion). The comparison of maximum detected concentrations in groundwater to EPA and CalEPA MCLs is presented in Table B-2.

B.1.2 Environmental Screening Levels

Environmental screening levels (ESLs) for the protection of indoor air from groundwater have been developed by the San Francisco Regional Water Quality Control Board (SFRWQCB 2003). These values are based on fate and transport characteristics of chemicals and their likelihood to be transported from the subsurface into indoor air. ESLs were calculated using spreadsheets provided with User's Guide for the Johnson and Ettinger Indoor Air model for Subsurface Vapor Intrusion Into Buildings (EPA 2003) assuming a vadose-zone thickness/depth to groundwater three meters. SFRWQCB values are used for this evaluation because groundwater concentrations for protection of indoor air have not been developed by the State of California. SFRWQCB screening concentrations are conservative values that are appropriate for COPC screening. Screening values for commercial/industrial land use and low to moderate permeability soils were used because the soil at Omega is primarily fine-grained and future use of the Site is likely to remain commercial/industrial. The comparison of maximum detected concentrations in groundwater to ESLs for groundwater is presented in Table B-3. Only PCE concentrations exceeded the relevant ESL.

B.1.3 EPA 2002 Guidance Target Groundwater Concentrations

EPA has generic target media-specific concentrations that are calculated to correspond to target indoor air concentrations using media-specific attenuation factors (EPA 2002). In the calculation of these values for groundwater, an attenuation factor of 0.001 was used and it was assumed that partitioning of chemicals between groundwater and soil vapor obeyed Henry's law. An attenuation factor of 0.001 is appropriate to represent an existing commercial building with a slab-on-grade foundation (EPA 2003). The EPA guidance document (EPA 2002) provides these generic target media-specific concentrations for target risk concentrations of 10^{-4} , 10^{-5} , and 10^{-6} . Maximum detected concentrations in groundwater were compared to the target risk concentration of 10^{-5} (10 in a million) in Table B-3. The 10 in a million target risk was selected because the federal government generally has found cancer risks of 10 in a million to be acceptable. That is, when acting under federal environmental laws, generally the government has taken no regulatory action to reduce cancer risks to less than one in a million, whereas in almost all cases the government has taken action when risks exceeded 10 in a million (EPA 1990; and Presidential/Congressional Commission on Risk Assessment and Risk Management 1997).

B.1.4 EPA Region 9 Preliminary Remediation Goals

The Region 9 preliminary remediation goals (PRGs) were also used as screening criteria for comparison with maximum detected concentrations. PRGs for groundwater are screening values that have been developed by EPA Region 9 (EPA 2004) based on residential and commercial/industrial exposure assumptions and a target cancer risk of 1×10^{-6} or target hazard quotient (HQ) of 1. For chemicals with carcinogenic as well as noncarcinogenic effects, the lower PRG is used in the COPC screening.

For groundwater, maximum concentrations for each chemical were compared to EPA Region IX tap water screening concentrations. Risk-based concentrations for non-volatile contaminants in tap water are "allowable" concentrations based on potential exposure from ingestion of groundwater. If a chemical was not detected in one of the media, the maximum reporting limit was compared to the screening concentration. The comparison of maximum detected concentrations in groundwater to PRGs is presented in Table B-3.

B.1.5 Frequency of Detection

Chemicals that are detected very infrequently at a Site generally are not likely to contribute significantly to overall risk. This is especially true for sites where risks are strongly dominated by a few chemicals; however, due to potential cumulative effects, no detected compounds are eliminated based solely on frequency of detection. Some compounds reported in samples collected from groundwater at the Site were infrequently detected (less than a 5 percent frequency) and generally are not expected to contribute significantly to potential overall risk.

These infrequently detected chemicals are further evaluated to assure that chemicals are not Class A carcinogens (known human carcinogens), are not detected at very high concentrations, and/or are not concentrated in "hotspots." Hotspots are defined as relatively small locations with chemical concentrations that are significantly higher than those in surrounding areas. In most cases, hotspots correlate with source areas. Chemicals classified as known human carcinogens, detected at very high concentrations, or concentrated in a hotspot area could theoretically be significant, even if their site-wide occurrence is low.

Frequency of detection is provided on Tables B-1 through B-3. A summary of the identified COPCs for the site is provided in Table B-4.

B.2 Exposure Assessment

Exposure is defined as human contact with a chemical or physical agent (EPA 1989). Exposure assessment is the estimation of magnitude, frequency, duration, and pathway(s) of exposure to a chemical. Assessment of exposure consists of three steps:

- Characterization of Exposure Setting
- Identification of Exposure Pathways
- Quantification of Exposure

In this stepwise risk evaluation, cumulative human health risks and hazards for chemicals in groundwater were estimated using Region 9 PRGs by applying the stepwise risk ratio approach. The PRGs combine human health toxicity values with standard exposure factors to estimate contaminant concentrations in environmental media through direct contact pathways for which generally accepted methods,

models, and assumptions have been developed. For groundwater, this includes ingestion from drinking, dermal absorption, and inhalation of volatiles.

The Region 9 PRGs for tap water assume ingestion from drinking during residential land use. However, groundwater within the contaminant area is currently not used for any purpose. Future use for potable purposes within this area is also unlikely due to the presence of high concentrations of total dissolved solids (TDS). In addition, the future use of the Site is likely to remain commercial/industrial. The assessment of risks based on potential domestic use of groundwater at the site is therefore extremely conservative.

The site conceptual exposure model for the Site outlining the actual potential receptors and exposure pathways for the Site is provided in Figure B-1.

B.3 Toxicity Assessment

The purpose of toxicity assessment is to review and summarize available information on the potential for each COPC to cause adverse effects in exposed individuals. For most adverse effects caused by chemicals, a positive relationship exists between dose (intake of a chemical through a particular exposure pathway, such as ingestion) and response. Generally, as dose increases, type and severity of adverse response also increases. Further, time of onset of toxic responses often shortens.

In this stepwise risk evaluation, cumulative human health risks and hazards for chemicals in groundwater were estimated using Region 9 PRGs by applying the stepwise risk ratio approach. As such, the toxicity values incorporated into the Region 9 PRGs are used. The user's guide for the PRGs provides a detailed description of the hierarchy of sources for the toxicity values that were used in the development of the PRGs. California-modified PRGs (based on CalEPA toxicity values) were used when provided.

B.4 Risk Characterization

The stepwise risk ratio approach for PRG screening of sites with multiple pollutants has three steps:

- Compile existing data (see Table B-1)
- Identify Site contaminants in the PRG Table (see Table B-3)
- Estimate risks and hazards by calculating ratios and summing for multiple chemicals

B.4.1 Cancer Risk

For cancer risk estimates of chemicals designated for cancer evaluation, the maximum detected site-specific concentration of the Phase 1a Area wells was divided by its respective PRG concentration. This ratio was multiplied by 10^{-6} to estimate chemical-

specific risk for a reasonable maximum exposure. The risks for each chemical were then summed to determine an overall cancer risk for the Site. All detected chemicals (not just the COPCs) were included in this evaluation.

As shown on Table B-5, the total cancer risk for the Site is 2.1. Commonly, risks (or odds) of developing cancer of one to 10 in one million (1×10^{-6} to 10×10^{-5}) or less are considered de minimis. Ninety-eight percent of the cancer risk is due to hypothetical exposure to tetrachloroethene (PCE).

PCE was detected in all of the groundwater samples with the highest concentrations detected in well OW-1. The maximum detected PCE concentration was 210,000 µg/L on August 2004. The most recent sampling in February 2005 indicated a PCE concentration of 170,000 µg/L. PCE concentrations in well OW-8 are a magnitude lower ranging from 3,400 to 68,000 µg/L from February 2004 to February 2005. Although PCE concentrations are lowest at the deeper wells OW-8B and OW-1B ranging from 2.1 to 90 µg/L, the average PCE concentrations at these wells are still high enough to cause a hypothetical cancer risk of greater than 1×10^{-4} .

B.4.2 Noncancer Hazard

For non-cancer risk estimates of chemicals designated for non-cancer evaluation, the maximum detected site-specific concentrations of the Phase 1a Area wells was divided by its respective PRG concentration to determine a non-carcinogenic hazard. The hazards for each chemical were then summed to determine an overall non-cancer hazard estimate for the Site. All detected chemicals (not just the COPCs) were included in this evaluation.

As shown on Table B-6, the total non-cancer risk for the Site is 59. A total hazard greater than one indicates an exposure greater than that considered safe. Thirty-five percent of the non-cancer hazard is due to exposure to bromomethane, and 11% is attributed to 1,1-dichloroethene (1,1-DCE). 1,1,1-Trichloroethane; 1,2,4-trimethylbenzene; chlorobenzene; and manganese each contribute 6% to 8% to the total non-cancer hazard.

Bromomethane was detected in 3 of 37 groundwater samples collected in 2004 and 2005 with the highest concentration of 180 µg/L detected in well OW-1. The other two detections of bromomethane were significantly lower (0.062 and 5.6 µg/L). These concentrations result in non-cancer hazards lower than the hazard threshold of one.

1,1-DCE was detected in 35 of 37 groundwater samples (95%) at concentrations ranging from 350 to 2,200 µg/L in wells OW-1, OW-2, OW-3 and OW-8. Because the tap water PRG for 1,1-DCE is 340 µg/L, concentrations higher than 340 µg/L result in a non-cancer hazard above one. Concentrations were significantly lower (0.56 to 6.1 µg/L) in the deeper wells, OW-1B and OW-8B.

B.4.3 Cumulative Risks and Hazards

The Phase 1a wells are OW-1, OW-1A, OW-2, OW-3, OW-8, and OW-8B. All other wells on the Omega facility are either upgradient wells or not within the Phase 1a Area. Due to the small number of wells, risk and hazard isopleths were not developed for the Site. Instead, risks and hazards were developed using the average 2004-2005 Site concentrations and plotted on Figures B-2 and B-3. Risks and hazards were highest at well location OW-1.

B.5 Uncertainties

B.5.1 Uncertainties in the Database

Site data for groundwater provide an adequate characterization of current groundwater conditions at the Site. However, data may not be fully adequate for determining future trends in soil gas contaminant concentrations. Since the database is a "snapshot" in time, it is not possible to determine with absolute certainty if vapor concentrations are likely to increase, decrease, or remain constant in the future. However, it is reasonable to assume that existing groundwater concentrations and, hence, volatilization therefrom, are not likely to increase significantly in the future.

B.5.2 Uncertainties with Exposure Assessment

The exposure assessment is based on a hypothetical drinking water scenario that is highly unlikely to ever be complete for the site. Risks presented in this appendix are not expressions of any risk that may actually be associated with VOCs in groundwater. However, given that the calculations were carried out, the following uncertainties pertain.

Quantitative estimates of chemical exposure may contain significant uncertainty. Exposure assumptions used in the development of PRGs are derived from a combination of USEPA and CalEPA guidance, site-specific information, and professional judgment, with each of the potential information sources being subject to uncertainty. The combination of exposure assumptions and exposure point concentrations used in the assessment is expected to provide conservative estimates for exposure of individuals at the Site. However, uncertainties and their potential impacts on use of risk results for risk management should be understood. In particular, the tap water PRGs were developed assuming a residential exposure. Because the Omega facility is an industrial site that is expected to remain industrial, using the PRGs that assume a residential scenario to calculate risks and hazards will over-estimate risks.

B.5.3 Uncertainties Associated with Toxicity Assessment

A potentially large source of uncertainty is inherent in the derivation of the EPA toxicity criteria (i.e., RfDs, and cancer slope factors). In many cases, data must be extrapolated from animals to sensitive humans by the application of uncertainty factors to an estimated no observable adverse effect levels (NOAELs) or low observable adverse effect levels (LOAEL) for non-cancer effects. While designed to be

protective, it is likely in many cases that uncertainty factors overestimate the magnitude of differences that may exist between human and animals, and among humans.

In some cases, however, toxicity criteria may be based on studies that did not detect the most sensitive adverse effects. For example, many past studies have not measured possible toxic effects on the immune system. Moreover, some chemicals may cause subtle effects not easily recognized in animal studies. The effects of lead on cognitive function and behavior at very low levels of exposure serve as examples.

In addition, derivation of cancer slope factors often involves linear extrapolation of effects at high doses to potential effects at lower doses commonly seen in environmental exposure settings. Currently, it is not known whether linear extrapolation is appropriate. Probably, the shape of the dose response curve for carcinogenesis varies with different chemicals and mechanisms of action. It is not possible at this time, however, to describe such differences in quantitative terms.

It is likely that the assumption of linearity is conservative and yields slope factors that are unlikely to lead to underestimation of risks. Yet, for specific chemicals, current methodology could cause slope factors, and, hence, risks, to be underestimated.

Use of the CalEPA toxicity criteria could either over or underestimate potential risks, but it is difficult to determine either the direction or magnitude of any errors. In general, however, it is likely that the criteria err on the side of protectiveness for most if not all chemicals.

B.5.4 Uncertainties with Risk Characterization

B.5.4.1 Noncancer Hazards

Some chemicals have both carcinogenic and noncarcinogenic effects. In the development of the PRG value, screening values were calculated for both carcinogenic and noncarcinogenic effects and the more conservative of the two values was presented in the PRG table as the screening value. This means that some carcinogens have an associated non-cancer PRG that is not listed in the PRG table. Thus, the non-cancer hazards calculated using the PRG table values underestimates the Site's overall non-cancer hazard. The unposted non-cancer PRG values could be obtained from the PRG InterCalc Tables to adjust the Site non-cancer hazard. However, because the Site's calculated non-cancer hazard is already 59 (significantly greater than one indicating that exposure is greater than that considered safe), a correction to make this value higher will not change the outcome that the exposure is greater than that considered safe.

B.5.4.2 Exposure to Chemicals without PRGs

A number of chemicals detected at the Omega Site do not have tap water PRGs. These chemicals are listed in Table B-7. Some of these chemicals are recognized as non-toxic and are essential minerals - sodium, potassium, magnesium, chloride, etc. - and their

exclusion from the risk assessment is unlikely to affect the results. However, some chemicals without PRGs can be associated with adverse effects.

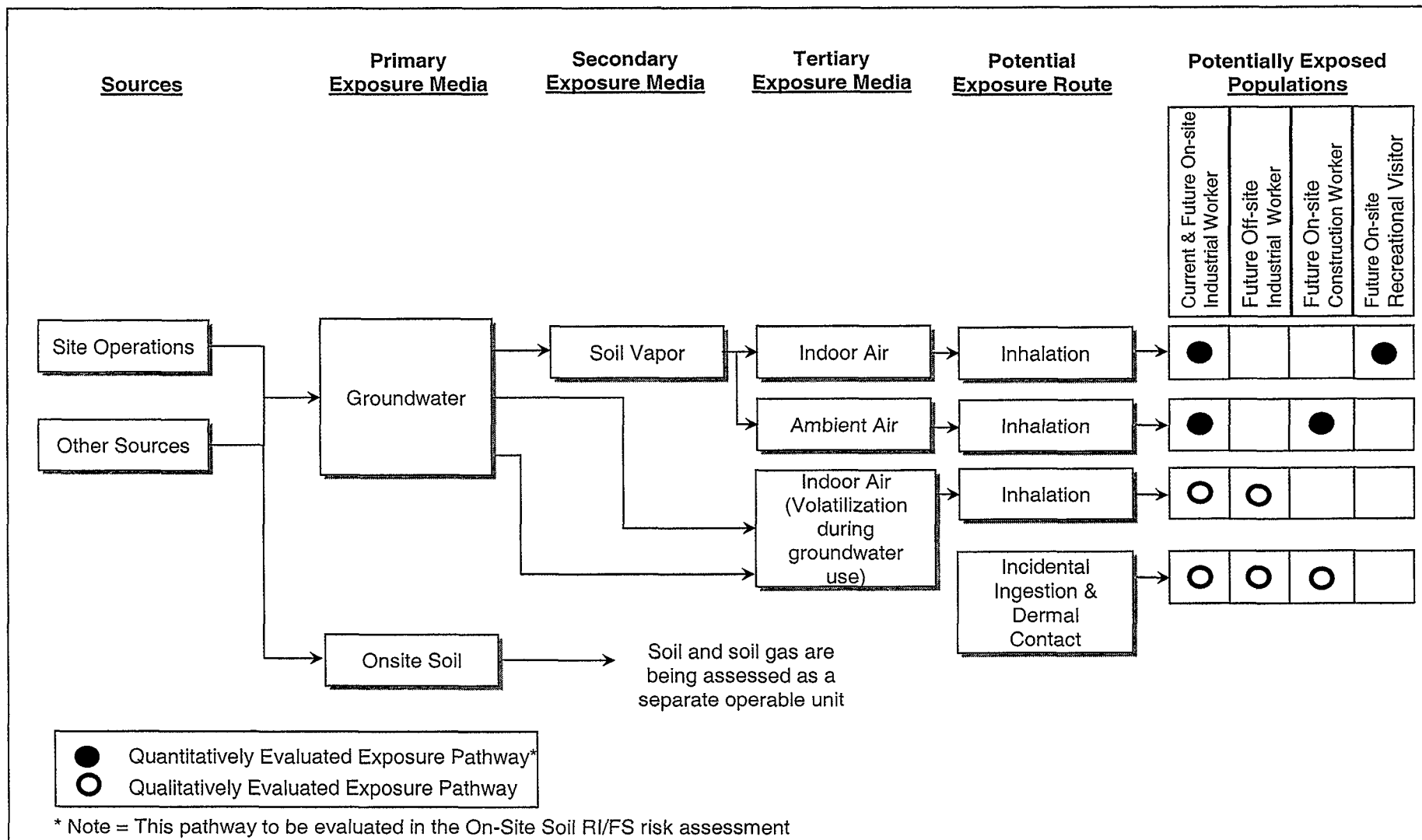
For example, the PRG table does not list a tap water PRG for lead. As such, the risks from exposure to lead were not calculated using the stepwise PRG approach. Risks and hazards from lead are usually calculated using the EPA Adult Lead model or the DTSC Leadsread model. Lead is classified as a probable human carcinogen, group B2 carcinogen, which means there is sufficient evidence of carcinogenicity in animals. Not including risk and hazards from lead results in an underestimate of risk. Because the Site's overall risk and hazard already indicate that exposure is greater than that considered safe, not including lead's contribution does not change the outcome of this evaluation.

B.6 Summary

The results of the stepwise risk evaluation for groundwater within the containment zone and the RI/FS for soil at the Omega Facility indicate that there is a need for remedial action if groundwater is to be used for as a source of potable water. The total cancer risk from groundwater at the Site is 2.1, which is several orders of magnitude above the acceptable range of 1×10^{-6} to 10×10^{-4} . Similarly, the total non-cancer risk for the Site is 59, significantly greater than the acceptable threshold of 1.

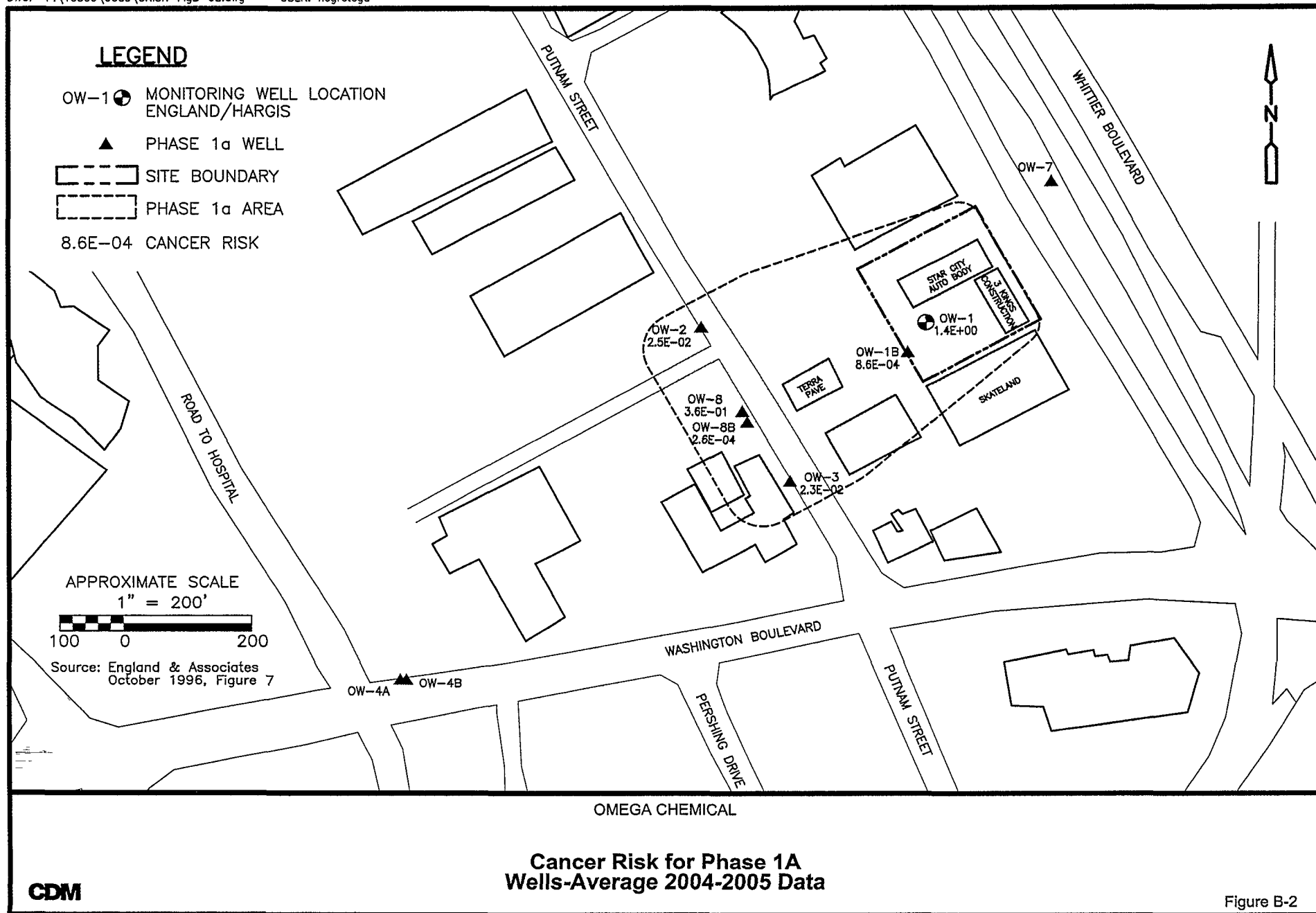
Because groundwater within the contaminant area (Gage aquifer) is currently not used and it is unlikely that it will be used for potable purposes in the future due to high concentrations of TDS, these calculated risks represent an unlikely future scenario. Further, tap water PRGs were developed assuming a residential exposure. Because the Omega facility is an industrial site that is expected to remain industrial, calculating site risks using these PRGs, which assume a residential scenario, overestimates risks. In addition, because groundwater at the site is greater than 70 feet below ground surface, off-gassing from groundwater is not expected to result in unacceptable risks. As noted previously, this stepwise human health risk ratio evaluation was conducted to provide Site management with additional information regarding potential health risk issues at the Site.

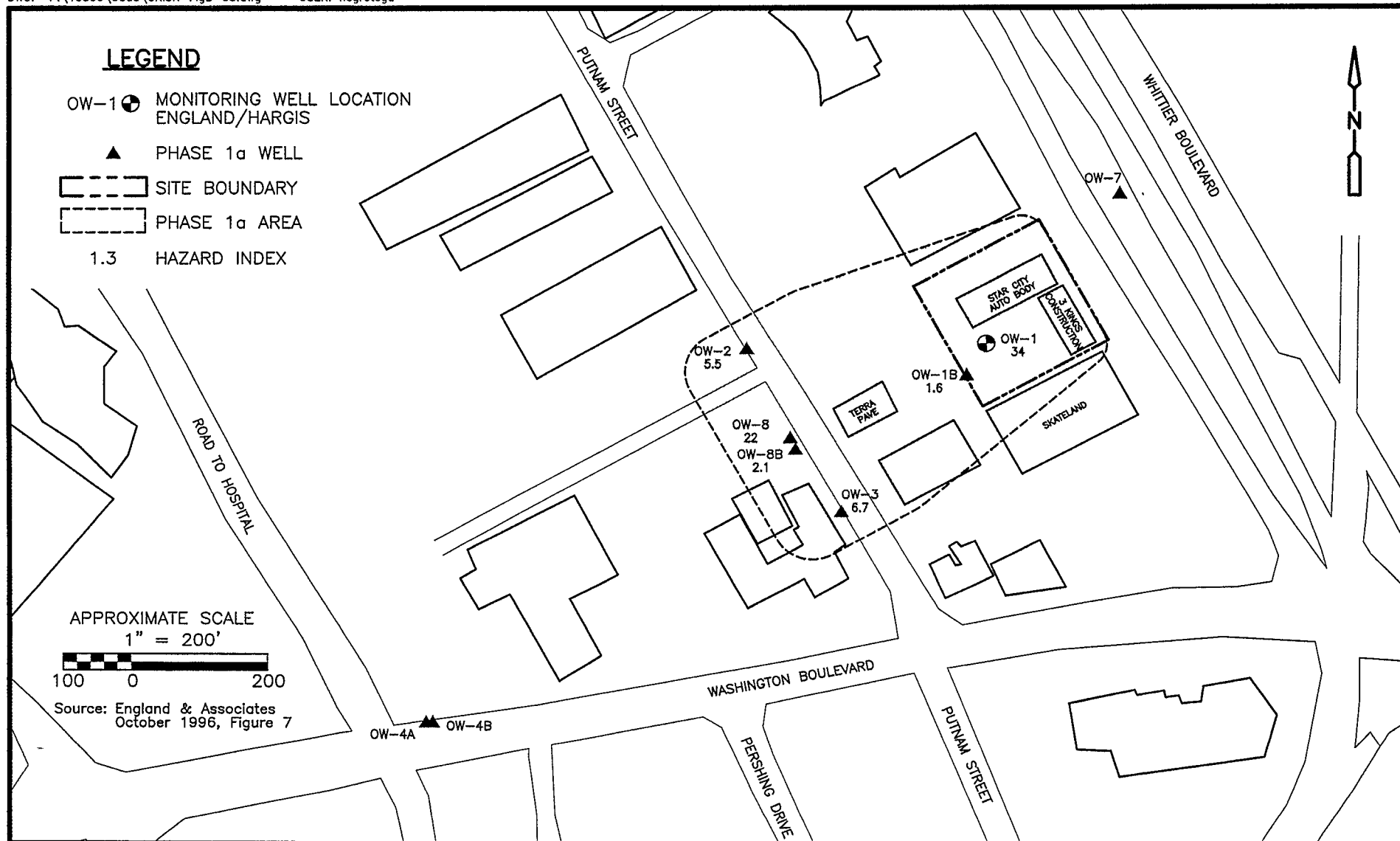
This EE/CA is focused on the limiting migration of VOCs in groundwater and this focus is consistent with the findings of the risk evaluation. Exposure to soil and soil gas will be evaluated in a separate risk assessment for the On-Site Soils RI/FS.



CDM

Figure B-1
Site Conceptual Exposure Model
Omega Chemical Site and Groundwater Contaminant Zone, California





OMEGA CHEMICAL

**Non-Cancer Hazards for Phase 1A
 Wells-Average 2004-2005 Data**

CDM

Figure B-3

Table B-1
Summary Statistics of Detected Chemicals in Phase 1A Wells Groundwater Data
2004-2005

Parameter	Units	Minimum	Maximum	Count	Total Count	Frequency
1,1,1,2-TETRACHLOROETHANE	ug/l	1.4	12	6	25	24%
1,1,1-TRICHLOROETHANE	ug/l	0.055	12000	27	37	73%
1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE	ug/l	0.14	2800	33	37	89%
1,1,2-TRICHLOROETHANE	ug/l	0.35	2000	9	37	24%
1,1-DICHLOROETHANE	ug/l	0.3	150	21	37	57%
1,1-DICHLOROETHENE	ug/l	0.56	2200	35	37	95%
1,2,3-TRICHLOROPROPANE	ng/L	14	87	3	36	8%
1,2,4-TRIMETHYLBENZENE	ug/l	0.8	52	3	25	12%
1,2-DICHLOROBENZENE	ug/l	3.8	39	6	37	16%
1,2-DICHLOROETHANE	ug/l	0.37	1300	16	37	43%
1,3,5-TRIMETHYLBENZENE	ug/l	13	13	1	25	4%
1,3-DICHLOROBENZENE	ug/l	0.48	1.4	6	37	16%
1,4-DICHLOROBENZENE	ug/l	0.89	3.6	6	37	16%
1,4-DIOXANE	ug/l	0.51	26000	25	36	69%
2-BUTANONE	ug/l	1.4	770	3	18	17%
2-CHLOROTOLUENE	ug/l	0.28	0.6	4	25	16%
2-METHYLNAPHTHALENE	ug/l	0.3	0.3	1	11	9%
ACETONE	ug/l	4.9	11000	14	37	38%
ACETOPHENONE	ug/l	2.2	6.9	2	11	18%
AMMONIA NITROGEN (AS N)	mg/L	0.23	0.29	2	11	18%
ANTIMONY	ug/l	0.18	1.9	7	11	64%
ARSENIC	ug/l	0.45	65	11	11	100%
BARIUM	ug/l	10	73	11	11	100%
BENZENE	ug/l	0.2	180	11	37	30%
BICARBONATE ALKALINITY (AS CaCO3)	mg/L	200	570	11	11	100%
BIS(2-ETHYLHEXYL)PHTHALATE	ug/l	0.62	2.5	3	11	27%
BOD 5 DAY (BIOCHEMICAL OXYGEN DEMAND)	mg/L	2	77	11	11	100%
BROMIDE	mg/L	0.14	70	11	11	100%
BROMOMETHANE	ug/l	0.062	180	3	37	8%
CADMIUM	ug/l	0.07	0.09	3	11	27%
CALCIUM	ug/l	49500	285999	11	11	100%
CAPROLACTAM	ug/l	4.2	28	3	11	27%
CARBON DISULFIDE	ug/l	0.28	240	4	13	31%
CARBON TETRACHLORIDE	ug/l	0.44	1	3	37	8%
CHEMICAL OXYGEN DEMAND	mg/L	3.8	301	9	11	82%
CHLORIDE	mg/L	40	370	11	11	100%
CHLOROBENZENE	ug/l	1.9	500	10	37	27%
CHLOROETHANE	ug/l	0.2	0.2	1	37	3%
CHLOROFORM	ug/l	0.3	2800	32	37	86%
CHLOROMETHANE	ug/l	0.4	2.6	3	37	8%
CHROMIUM	ug/l	0.28	5.1	6	11	55%
CHROMIUM (VI)	ug/l	2.1	4.2	6	12	50%
CIS-1,2-DICHLOROETHENE	ug/l	0.21	25	12	37	32%
COBALT	ug/l	0.12	2.7	10	11	91%
COPPER	ug/l	0.41	1	9	11	82%
CYANIDE, TOTAL	ug/l	2	3.4	2	11	18%
CYCLOHEXANE	ug/l	1	1	1	13	8%
DICHLORODIFLUOROMETHANE	ug/l	0.5	1.2	4	37	11%
DIMETHYL PHTHALATE	ug/l	0.68	0.68	1	11	9%
ETHYLBENZENE	ug/l	3.1	41	7	37	19%
FLUORIDE	mg/L	0.16	0.47	11	11	100%
IRON	ug/l	37	3350	7	11	64%
ISOPHORONE	ug/l	2.2	4.9	2	11	18%
ISOPROPYL ALCOHOL (ISOPROPANOL)	ug/l	140	140	1	1	100%
ISOPROPYLBENZENE	ug/l	1.5	6.7	6	37	16%
LEAD	ug/l	0.02	0.31	8	11	73%
M,P-XYLENES	ug/l	0.3	130	7	25	28%

Table B-1
Summary Statistics of Detected Chemicals in Phase 1A Wells Groundwater Data
2004-2005

Parameter	Units	Minimum	Maximum	Count	Total Count	Frequency
MAGNESIUM	ug/l	40100	99999	11	11	100%
MANGANESE	ug/l	0.53	4010	11	11	100%
MERCURY	ug/l	0.02	0.19	4	11	36%
METHYL ACETATE	ug/l	1300	1300	1	12	8%
METHYL TERT-BUTYL ETHER	ug/l	0.3	1.3	3	37	8%
METHYLENE CHLORIDE	ug/l	0.25	9200	15	37	41%
NAPHTHALENE	ug/l	0.21	1.6	6	36	17%
NICKEL	ug/l	1.2	13	11	11	100%
NITRATE (AS N)	mg/L	0.17	14	11	11	100%
NITRITE (AS N)	mg/L	0.06	0.57	9	11	82%
N-NITROSODIMETHYLAMINE	ng/L	230	900	3	11	27%
N-PROPYLBENZENE	ug/l	0.42	5.7	6	25	24%
O-XYLENE	ug/l	0.55	81	9	25	36%
PENTACHLOROPHENOL (PCP)	ug/l	0.3	0.3	1	11	9%
PERCHLORATE	ug/l	1.2	3.8	9	11	82%
PHENANTHRENE	ug/l	0.069	0.069	1	11	9%
PHENOL	ug/l	8.5	20	2	11	18%
P-ISOPROPYLTOLUENE	ug/l	0.29	0.86	6	25	24%
POTASSIUM	ug/l	1860	5280	6	11	55%
SEC-BUTYLBENZENE	ug/l	0.26	0.39	3	25	12%
SELENIUM	ug/l	1	227	11	11	100%
SODIUM	ug/l	68600	125001	11	11	100%
SULFATE	mg/L	95	430	11	11	100%
TENTATIVELY IDENTIFIED COMPOUND	ug/l	1.1	1.1	1	6	17%
TETRACHLOROETHENE	ug/l	2.1	210000	37	37	100%
TETRAHYDROFURAN	ug/l	650	650	1	1	100%
TOLUENE	ug/l	1.1	1300	17	37	46%
TOTAL ALKALINITY (AS CaCO3)	mg/L	200	570	11	11	100%
TOTAL DISSOLVED SOLIDS	mg/L	630	1500	11	11	100%
TOTAL INORGANIC CARBON	ug/l	1.1	1.1	1	1	100%
TOTAL KJELDAHL NITROGEN (ORGANIC NITRO)	mg/L	0.22	1	7	11	64%
TOTAL ORGANIC CARBON	mg/L	5	74	12	12	100%
TOTAL PHOSPHORUS	mg/L	0.32	0.32	1	11	9%
TOTAL XYLENES	ug/l	0.055	75	2	12	17%
TRANS-1,2-DICHLOROETHENE	ug/l	0.79	130	13	37	35%
TRICHLOROETHENE	ug/l	0.16	3600	35	37	95%
TRICHLOROFLUOROMETHANE	ug/l	0.6	950	31	37	84%
VANADIUM	ug/l	0.35	4.9	9	11	82%
VINYL CHLORIDE	ug/l	0.5	0.9	4	37	11%
ZINC	ug/l	1.6	15	11	11	100%

ug/L = micrograms per liter

mg/L = milligrams per liter

ng/L = nanograms per liter

Table B-2
Comparison of Maximum Detected Groundwater Concentrations in Phase 1A Wells to EPA Maximum Contaminant Levels (MCLs) and CalEPA
MCLs
2004-2005

Parameter	EPA MCL (ug/L)		CalEPA MCL (ug/L)		Maximum Detected Concentration	Frequency
	Primary	Secondary	Primary	Secondary		
1,1,1,2-TETRACHLOROETHANE	—	—	—	—	12 ug/l	24%
1,1,1-TRICHLOROETHANE	200 *	—	200 *	—	12,000 ug/l	73%
1,1,2-TRICHLOROETHANE	5 *	—	5 *	—	2,000 ug/l	24%
1,1-DICHLOROETHANE	—	—	5 *	—	150 ug/l	57%
1,1-DICHLOROETHENE	7 *	—	6 *	—	2,200 ug/l	95%
1,2,3-TRICHLOROPROPANE	—	—	—	—	87 ng/L	8%
1,2,4-TRIMETHYLBENZENE	—	—	—	—	52 ug/l	12%
1,2-DICHLOROBENZENE	600	100	600	—	39 ug/l	16%
1,2-DICHLOROETHANE	5 *	—	0.5 *	—	1,300 ug/l	43%
CIS-1,2-DICHLOROETHENE	70	—	6 *	—	25 ug/l	32%
TRANS-1,2-DICHLOROETHENE	100 *	—	10 *	—	130 ug/l	35%
1,3,5-TRIMETHYLBENZENE	—	—	—	—	13 ug/l	4%
1,3-DICHLOROBENZENE	—	—	—	—	1.4 ug/l	16%
1,4-DICHLOROBENZENE	75	5	5	—	3.6 ug/l	16%
1,4-DIOXANE	3 *	—	3 *	—	26,000 ug/l	69%
2-BUTANONE	—	—	—	—	770 ug/l	17%
2-METHYLNAPHTHALENE	—	—	—	—	0.3 ug/l	9%
ACETONE	—	—	—	—	11,000 ug/l	38%
ACETOPHENONE	—	—	—	—	6.9 ug/l	18%
AMMONIA NITROGEN (AS N)	—	—	—	—	0.29 mg/L	18%
ANTIMONY	6	—	6	—	1.9 ug/l	64%
ARSENIC	50 *	—	50 *	—	65 ug/l	100%
BARIUM	2,000	—	1,000	—	73 ug/l	100%
BENZENE	5 *	—	1 *	—	180 ug/l	30%
BICARBONATE ALKALINITY (AS CaCO3)	—	—	—	—	570 mg/L	100%
BIS(2-ETHYLHEXYL)PHTHALATE	—	—	—	—	2.5 ug/l	27%
BOD 5 DAY (BIOCHEMICAL OXYGEN DEMAND)	—	—	—	—	77 mg/L	100%
BROMIDE	—	—	—	—	70 mg/L	100%
BROMOMETHANE	—	—	—	—	180 ug/l	8%
CADMIUM	5	—	5	—	0.09 ug/l	27%
CALCIUM	—	—	—	—	285,999 ug/l	100%
CAPROLACTAM	—	—	—	—	28 ug/l	27%
CARBON DISULFIDE	—	—	—	—	240 ug/l	31%
CARBON TETRACHLORIDE	5	—	0.5 *	—	1 ug/l	8%
CHEMICAL OXYGEN DEMAND	—	—	—	—	301 mg/L	82%
CHLORIDE	—	250,000 *	—	—	370 mg/L	100%
CHLOROBENZENE	100 *	—	70 *	—	500 ug/l	27%
CHLOROETHANE	—	—	—	—	0.2 ug/l	3%
CHLOROFORM	80 *	—	100 *	—	2,800 ug/l	86%
CHLOROMETHANE	—	—	—	—	2.6 ug/l	8%
CHROMIUM	100	—	50	—	5.1 ug/l	55%
CHROMIUM (VI)	14	—	7	—	4.2 ug/l	50%
COBALT	—	—	—	—	2.7 ug/l	91%
COPPER	1,300	1,000	1,300	—	1 ug/l	82%
CYANIDE, TOTAL	200	—	150	—	3.4 ug/l	18%
CYCLOHEXANE	—	—	—	—	1 ug/l	8%
DICHLORODIFLUOROMETHANE	—	—	—	—	1.2 ug/l	11%
DIMETHYL PHTHALATE	—	—	—	—	0.68 ug/l	9%
ETHYLBENZENE	700	30 *	300	—	41 ug/l	19%
FLUORIDE	4,000	2,000	2,000	—	0.47 mg/L	100%
1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE	—	—	1,200 *	—	2,800 ug/l	89%
IRON	—	300 *	—	300 *	3,350 ug/l	64%
ISOPHORONE	—	—	—	—	4.9 ug/l	18%
ISOPROPYL ALCOHOL (ISOPROPANOL)	—	—	—	—	140 ug/l	100%
ISOPROPYLBENZENE	—	—	—	—	6.7 ug/l	16%
LEAD	15	—	—	—	0.31 ug/l	73%
MAGNESIUM	—	—	—	—	99,999 ug/l	100%
MANGANESE	—	50 *	—	50 *	4,010 ug/l	100%
MERCURY	2	—	2	—	0.19 ug/l	36%
METHYL ACETATE	—	—	—	—	1300 ug/l	8%
METHYL TERT-BUTYL ETHER	—	—	13	5	1.3 ug/l	8%
METHYLENE CHLORIDE	5 *	—	5 *	—	9,200 ug/l	41%
NAPHTHALENE	—	—	—	—	1.6 ug/l	17%
NICKEL	—	—	100	—	13 ug/l	100%
NITRATE (AS N)	10,000 *	—	—	—	14 mg/L	100%

Table B-2
Comparison of Maximum Detected Groundwater Concentrations in Phase 1A Wells to EPA Maximum Contaminant Levels (MCLs) and CalEPA
MCLs
2004-2005

Parameter	EPA MCL (ug/L)		CalEPA MCL (ug/L)		Maximum Detected Concentration	Frequency
	Primary	Secondary	Primary	Secondary		
NITRITE (AS N)	1,000	—	1,000	—	0.57 mg/L	82%
N-NITROSODIMETHYLAMINE	—	—	—	—	900 ng/L	27%
N-PROPYLBENZENE	—	—	—	—	5.7 ug/l	24%
2-CHLOROTOLUENE	—	—	—	—	0.6 ug/l	16%
PENTACHLOROPHENOL (PCP)	1	—	1	—	0.3 ug/l	9%
PERCHLORATE	—	—	—	—	3.8 ug/l	82%
PHENANTHRENE	—	—	—	—	0.069 ug/l	9%
PHENOL	—	—	—	—	20 ug/l	18%
P-ISOPROPYLTOLUENE	—	—	—	—	0.86 ug/l	24%
POTASSIUM	—	—	—	—	5280 ug/l	55%
SEC-BUTYLBENZENE	—	—	—	—	0.39 ug/l	12%
SELENIUM	50 *	—	50 *	—	227 ug/l	100%
SODIUM	—	—	—	—	125,001 ug/l	100%
SULFATE	—	250 *	—	—	430 mg/L	100%
TENTATIVELY IDENTIFIED COMPOUND	—	—	—	—	1.1 ug/l	17%
TETRACHLOROETHENE	5 *	—	5 *	—	210,000 ug/l	100%
TETRAHYDROFURAN	—	—	—	—	650 ug/l	100%
TOLUENE	1,000 *	40 *	150 *	—	1,300 ug/l	46%
TOTAL ALKALINITY (AS CaCO3)	—	—	—	—	570 mg/L	100%
TOTAL DISSOLVED SOLIDS	—	500,000 *	—	—	1,500 mg/L	100%
TOTAL INORGANIC CARBON	—	—	—	—	1.1 ug/l	100%
TOTAL KJELDAHL NITROGEN (ORGANIC NITRO)	—	—	—	—	1 mg/L	64%
TOTAL ORGANIC CARBON	—	—	—	—	74 mg/L	100%
TOTAL PHOSPHORUS	—	—	—	—	0.32 mg/L	9%
TRICHLOROETHENE	5 *	—	5 *	—	3,600 ug/l	95%
TRICHLOROFLUOROMETHANE	—	—	150 *	—	950 ug/l	84%
VANADIUM	—	—	—	—	4.9 ug/l	82%
VINYL CHLORIDE	2	—	0.5 *	—	0.9 ug/l	11%
M,P-XYLENES	—	—	—	—	130 ug/l	28%
O-XYLENE	—	—	—	—	81 ug/l	36%
TOTAL XYLENES	10,000	20 *	1,750	—	75 ug/l	17%
ZINC	—	5,000	—	5000	15 ug/l	100%

EPA = U.S. Environmental Protection Agency

CalEPA = California Environmental Protection Agency

MCL = Maximum Contaminant Level

ug/L = micrograms per liter

mg/L = milligrams per liter

ng/L = nanograms per liter

* = Maximum detected concentration exceeds this value

Note: For Chromium (VI), a 1:6 ratio was assumed for Chromium (VI):Total Chromium to estimate a MCL from the total Chromium MCL.

There is no specified MCL for Chromium (VI).

Table B-3
Comparison of Maximum Detected Groundwater Concentrations in Phase 1A Wells
to SF RWQCB ESLs and EPA Region 9 PRGs
2004-2005

Parameter	SFRWQCB ESLs Commercial/Industrial Low to Moderate Permeability Soils (ug/L)	EPA 2002 Guidance Target Groundwater Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.001 and Partitioning Across the Water Table Obeys Henry's Law for Target Risk = 10^{-5} (ug/L)	EPA Region IX Tap Water PRG (ug/L)	Maximum Detected Concentration	Count	Total Count	Frequency
1,1,1,2-TETRACHLOROETHANE	(NV: Use soil gas)	33	0.43 *	12 ug/l	6	25	24%
1,1,1-TRICHLOROETHANE	1,300,000	3100 *	3,172 *	12,000 ug/l	27	37	73%
1,1,2-TRICHLOROETHANE	2,700	41 *	0.20 *	2,000 ug/l	9	37	24%
1,1-DICHLOROETHANE	12,000	2200	811	150 ug/l	21	37	57%
1,1-DICHLOROETHENE	75,000	190 *	339 *	2,200 ug/l	35	37	95%
1,2,3-TRICHLOROPROPANE	—	290	0.01 *	87 ng/L	3	36	8%
1,2,4-TRIMETHYLBENZENE	—	24 *	12.33 *	52 ug/l	3	25	12%
1,2-DICHLOROBENZENE	160,000	2600	370	39 ug/l	6	37	16%
1,2-DICHLOROETHANE	1,700	23 *	0.12 *	1,300 ug/l	16	37	43%
CIS-1,2-DICHLOROETHENE	55,000	210	60.83	25 ug/l	12	37	32%
TRANS-1,2-DICHLOROETHENE	69,000	180	122 *	130 ug/l	13	37	35%
1,3,5-TRIMETHYLBENZENE	—	25	12.33 *	13 ug/l	1	25	4%
1,3-DICHLOROBENZENE	(NV: Use soil gas)	830	183	1.4 ug/l	6	37	16%
1,4-DICHLOROBENZENE	3,400	8200	0.50 *	3.6 ug/l	6	37	16%
1,4-DIOXANE	NV	—	6.11 *	26,000 ug/l	25	36	69%
2-BUTANONE	330,000,000	440000	—	770 ug/l	3	18	17%
2-METHYLNAPHTHALENE	26,000	3300	—	0.3 ug/l	1	11	9%
ACETONE	22,000,000	220000	5,475 *	11,000 ug/l	14	37	38%
ACETOPHENONE	—	800000	—	6.9 ug/l	2	11	18%
AMMONIA NITROGEN (AS N)	—	—	—	0.29 mg/L	2	11	18%
ANTIMONY	NV	—	0.01 *	1.9 ug/l	7	11	64%
ARSENIC	NV	—	0.04 *	65 ug/l	11	11	100%
BARIUM	NV	—	2,555	73 ug/l	11	11	100%
BENZENE	6,400	14 *	0.35 *	180 ug/l	11	37	30%
BICARBONATE ALKALINITY (AS CaCO ₃)	—	—	—	570 mg/L	11	11	100%
BIS(2-ETHYLHEXYL)PHTHALATE	NV	—	4.80	2.5 ug/l	3	11	27%
BOD 5 DAY (BIOCHEMICAL OXYGEN DEMAND)	—	—	—	77 mg/L	11	11	100%
BROMIDE	—	—	—	70 mg/L	11	11	100%
BROMOMETHANE	5,700	—	8.66 *	180 ug/l	3	37	8%
CADMIUM	NV	—	18.25	0.09 ug/l	3	11	27%
CALCIUM	—	—	—	285,999 ug/l	11	11	100%
CAPROLACTAM	—	—	18,250	28 ug/l	3	11	27%
CARBON DISULFIDE	—	560	1,043	240 ug/l	4	13	31%
CARBON TETRACHLORIDE	140	5	0.17 *	1 ug/l	3	37	8%
CHEMICAL OXYGEN DEMAND	—	—	—	301 mg/L	9	11	82%
CHLORIDE	—	—	—	370 mg/L	11	11	100%
CHLOROBENZENE	120,000	390 *	106 *	500 ug/l	10	37	27%
CHLOROETHANE	11,000	28000	4.64	0.2 ug/l	1	37	3%
CHLOROFORM	3,900	80 *	0.53 *	2,800 ug/l	32	37	86%
CHLOROMETHANE	2,500	—	158	2.6 ug/l	3	37	8%

Table B-3
Comparison of Maximum Detected Groundwater Concentrations in Phase 1A Wells
to SF RWQCB ESLs and EPA Region 9 PRGs
2004-2005

Parameter	SFRWQCB ESLs Commercial/Industrial Low to Moderate Permeability Soils (ug/L)	EPA 2002 Guidance Target Groundwater Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.001 and Partitioning Across the Water Table Obeys Henry's Law for Target Risk = 10^{-5} (ug/L)	EPA Region IX Tap Water PRG (ug/L)	Maximum Detected Concentration	Count	Total Count	Frequency
CHROMIUM	NV	—	54,747	5.1 ug/l	6	11	55%
CHROMIUM (VI)	NV	—	109	4.2 ug/l	6	12	50%
COBALT	NV	—	730	2.7 ug/l	10	11	91%
COPPER	NV	—	1,460	1 ug/l	9	11	82%
CYANIDE, TOTAL	NV	—	730	3.4 ug/l	2	11	18%
CYCLOHEXANE	—	—	10,342	1 ug/l	1	13	8%
DICHLORODIFLUOROMETHANE	—	14	395	1.2 ug/l	4	37	11%
DIMETHYL PHTHALATE	NV	—	364,867	0.68 ug/l	1	11	9%
ETHYLBENZENE	180,000	700	1,340	41 ug/l	7	37	19%
FLUORIDE	—	—	—	0.47 mg/L	11	11	100%
1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE	—	1500 *	59,180	2,800 ug/l	33	37	89%
IRON	—	—	10,950	3,350 ug/l	7	11	64%
ISOPHORONE	—	—	70.77	4.9 ug/l	2	11	18%
ISOPROPYL ALCOHOL (ISOPROPANOL)	—	—	—	140 ug/l	1	1	100%
ISOPROPYLBENZENE	—	—	—	6.7 ug/l	6	37	16%
LEAD	NV	—	—	0.31 ug/l	8	11	73%
MAGNESIUM	—	—	—	99,999 ug/l	11	11	100%
MANGANESE	—	—	876 *	4010 ug/l	11	11	100%
MERCURY	NV	0.68	10.95	0.19 ug/l	4	11	36%
METHYL ACETATE	—	720000	6,083	1,300 ug/l	1	12	8%
METHYL TERT-BUTYL ETHER	160,000	120000	11.00	1.3 ug/l	3	37	8%
METHYLENE CHLORIDE	24,000	580 *	4.28 *	9,200 ug/l	15	37	41%
NAPHTHALENE	31,000	150	6.20	1.6 ug/l	6	36	17%
NICKEL	NV	—	730	13 ug/l	11	11	100%
NITRATE (AS N)	—	—	10,000 *	14 mg/L	11	11	100%
NITRITE (AS N)	—	—	1,000	0.57 mg/L	9	11	82%
N-NITROSODIMETHYLAMINE	—	—	0.0013 *	900 ng/L	3	11	27%
N-PROPYLBENZENE	—	320	243	5.7 ug/l	6	25	24%
2-CHLOROTOLUENE	—	—	122	0.6 ug/l	4	25	16%
PENTACHLOROPHENOL (PCP)	NV	—	0.56	0.3 ug/l	1	11	9%
PERCHLORATE	NV	—	3.65 *	3.8 ug/l	9	11	82%
PHENANTHRENE	(NV: Use soil gas)	—	—	0.069 ug/l	1	11	9%
PHENOL	NV	—	10,950	20 ug/l	2	11	18%
P-ISOPROPYLTOLUENE	—	—	—	0.86 ug/l	6	25	24%
POTASSIUM	—	—	—	5,280 ug/l	6	11	55%
SEC-BUTYLBENZENE	—	250	243	0.39 ug/l	3	25	12%
SELENIUM	NV	—	182 *	227 ug/l	11	11	100%
SODIUM	—	—	—	125,001 ug/l	11	11	100%
SULFATE	—	—	—	430 mg/L	11	11	100%
TENTATIVELY IDENTIFIED COMPOUND	—	—	—	1.1 ug/l	1	6	17%

Table B-3
Comparison of Maximum Detected Groundwater Concentrations in Phase 1A Wells
to SF RWQCB ESLs and EPA Region 9 PRGs
2004-2005

Parameter	SFRWQCB ESLs Commercial/Industrial Low to Moderate Permeability Soils (ug/L)	EPA 2002 Guidance Target Groundwater Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.001 and Partitioning Across the Water Table Obeys Henry's Law for Target Risk = 10^{-5} (ug/L)	EPA Region IX Tap Water PRG (ug/L)	Maximum Detected Concentration	Count	Total Count	Frequency
TETRACHLOROETHENE	1,700 *	11 *	0.10 *	210,000 ug/l	37	37	100%
TETRAHYDROFURAN	—	—	1.62 *	650 ug/l	1	1	100%
TOLUENE	530,000	1500	723 *	1,300 ug/l	17	37	46%
TOTAL ALKALINITY (AS CaCO ₃)	—	—	—	570 mg/L	11	11	100%
TOTAL DISSOLVED SOLIDS	—	—	—	1,500 mg/L	11	11	100%
TOTAL INORGANIC CARBON	—	—	—	1.1 ug/l	1	1	100%
TOTAL KJELDAHL NITROGEN (ORGANIC NITRO)	—	—	—	1 mg/L	7	11	64%
TOTAL ORGANIC CARBON	—	—	—	74 mg/L	12	12	100%
TOTAL PHOSPHORUS	—	—	—	0.32 mg/L	1	11	9%
TRICHLOROETHENE	6,900	5 *	1.40 *	3,600 ug/l	35	37	95%
TRICHLOROFLUOROMETHANE	—	180 *	1,288	950 ug/l	31	37	84%
VANADIUM	NV	—	36.50	4.9 ug/l	9	11	82%
VINYL CHLORIDE	57	2.5	0.02 *	0.9 ug/l	4	37	11%
M,P-XYLENES	—	22000	206	130 ug/l	7	25	28%
O-XYLENE	—	33000	206	81 ug/l	9	25	36%
TOTAL XYLENES	160,000	—	206	75 ug/l	2	12	17%
ZINC	NV	—	10,950	15 ug/l	11	11	100%

* = Maximum detected concentration exceeds this value

NV = no value. Use soil gas data to evaluate potential indoor-air impact concerns.

— = not listed

SFRWQCB = San Francisco Regional Water Quality Control Board

ESLs = Environmental Screening Levels

PRGs = Preliminary Remediation Goals

ug/L = micrograms per liter

mg/L = milligrams per liter

ng/L = nanograms per liter

Note: ESLs calculated using spreadsheet provided with User's Guide for the Johnson and Ettinger Indoor Air model (1991) for Subsurface Vapor Intrusion Into Buildings (USEPA 2001). Assumed vadose-zone thickness/depth to groundwater three meters.

Table B-4
Summary of Contaminants of Potential Concern
2004-2005

Parameter	Basis of COPC Selection					Frequency of Detection
	Exceeds EPA MCL	Exceeds CalEPA MCL	Exceeds SFRWQCB ESL	Exceeds EPA 2002 Guidance	Exceeds Region 9 Tap Water PRGs	
1,1,1,2-TETRACHLOROETHANE					X	24%
1,1,1-TRICHLOROETHANE	Primary	Primary		X	X	73%
1,1,2-TRICHLOROETHANE	Primary	Primary		X	X	24%
1,1-DICHLOROETHANE		Primary				57%
1,1-DICHLOROETHENE	Primary	Primary		X	X	95%
1,2,3-TRICHLOROPROPANE					X	8%
1,2,4-TRIMETHYLBENZENE				X	X	12%
1,2-DICHLOROETHANE	Primary	Primary			X	43%
CIS-1,2-DICHLOROETHENE		Primary				32%
TRANS-1,2-DICHLOROETHENE	Primary	Primary			X	35%
1,3,5-TRIMETHYLBENZENE					X	4%
1,4-DICHLOROBENZENE					X	16%
1,4-DIOXANE	Primary	Primary			X	69%
ACETONE					X	38%
ANTIMONY					X	64%
ARSENIC	Primary	Primary			X	100%
BENZENE	Primary	Primary		X	X	30%
BROMOMETHANE					X	8%
CARBON TETRACHLORIDE		Primary			X	8%
CHLORIDE	Secondary					100%
CHLOROBENZENE	Primary	Primary		X	X	27%
CHLOROFORM	Primary	Primary		X	X	86%
ETHYLBENZENE	Secondary					19%
1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE		Primary		X		89%
IRON	Secondary	Secondary				64%
MANGANESE	Secondary	Secondary			X	100%
METHYLENE CHLORIDE	Primary	Primary		X	X	41%
NITRATE (AS N)	Primary				X	100%
N-NITROSODIMETHYLAMINE					X	27%
PERCHLORATE					X	82%
SELENIUM	Primary	Primary			X	100%
SULFATE	Secondary					100%
TETRACHLOROETHENE	Primary	Primary	X	X	X	100%
TETRAHYDROFURAN					X	100%
TOLUENE	Primary	Primary			X	46%
TOTAL DISSOLVED SOLIDS	Secondary					100%
TRICHLOROETHENE	Primary	Primary		X	X	95%
TRICHLOROFLUOROMETHANE		Primary		X		84%
VINYL CHLORIDE		Primary			X	11%
TOTAL XYLENES	Secondary					17%

SFRWQCB = San Francisco Regional Water Quality Control Board

ESLs = Environmental Screening Levels

PRGs = Preliminary Remediation Goals

EPA = U.S. Environmental Protection Agency

CalEPA = California Environmental Protection Agency

MCL = Maximum Contaminant Level

COPC = Chemical of Potential Concern

Table B-5
Screening Calculation of Cancer Risks from Maximum Detected Concentrations in Groundwater at Phase 1A Wells
2004-2005

Parameter	EPA Region IX Tap Water PRG (ug/L)	Units	Minimum	Maximum	Count	Total Count	Frequency	Ratio Conc/PRG	Risk
NAPHTHALENE	9.3E-02 ca	ug/l	0.21	1.6	6	36	17%	1.7E+01	1.7E-05
1,1,1,2-TETRACHLOROETHANE	4.3E-01 ca	ug/l	1.4	12	6	25	24%	2.8E+01	2.8E-05
1,1,2-TRICHLOROETHANE	2.0E-01 ca	ug/l	0.35	2000	9	37	24%	1.0E+04	1.0E-02
1,2,3-TRICHLOROPROPANE	5.6E-03 ca	ng/L	14	87	3	36	8%	1.6E+01	1.6E-05
1,4-DICHLOROBENZENE	5.0E-01 ca	ug/l	0.89	3.6	6	37	16%	7.2E+00	7.2E-06
1,4-DIOXANE	6.1E+00 ca	ug/l	0.51	26000	25	36	69%	4.3E+03	4.3E-03
ARSENIC	7.1E-03 ca	ug/l	0.45	65	11	11	100%	9.2E+03	9.2E-03
BENZENE	3.5E-01 ca	ug/l	0.2	180	11	37	30%	5.1E+02	5.1E-04
BIS(2-ETHYLHEXYL)PHTHALATE	4.8E+00 ca	ug/l	0.62	2.5	3	11	27%	5.2E-01	5.2E-07
CHLOROETHANE	4.6E+00 ca	ug/l	0.2	0.2	1	37	3%	4.3E-02	4.3E-08
CHLOROFORM	5.3E-01 ca	ug/l	0.3	2800	32	37	86%	5.2E+03	5.2E-03
ISOPHORONE	7.1E+01 ca	ug/l	2.2	4.9	2	11	18%	6.9E-02	6.9E-08
METHYL TERT-BUTYL ETHER	1.1E+01 ca	ug/l	0.3	1.3	3	37	8%	1.2E-01	1.2E-07
METHYLENE CHLORIDE	4.3E+00 ca	ug/l	0.25	9200	15	37	41%	2.2E+03	2.2E-03
N-NITROSODIMETHYLAMINE	1.3E-03 ca	ng/L	230	900	3	11	27%	6.8E+02	6.8E-04
PENTACHLOROPHENOL (PCP)	5.6E-01 ca	ug/l	0.3	0.3	1	11	9%	5.4E-01	5.4E-07
TETRACHLOROETHENE	1.0E-01 ca	ug/l	2.1	210000	37	37	100%	2.0E+06	2.0E+00
TETRAHYDROFURAN	1.6E+00 ca	ug/l	650	650	1	1	100%	4.0E+02	4.0E-04
TRICHLOROETHENE	1.4E+00 ca	ug/l	0.16	3600	35	37	95%	2.6E+03	2.6E-03
VINYL CHLORIDE	2.0E-02 ca	ug/l	0.5	0.9	4	37	11%	4.5E+01	4.5E-05
1,2-DICHLOROETHANE	1.2E-01 ca*	ug/l	0.37	1300	16	37	43%	1.1E+04	1.1E-02
CARBON TETRACHLORIDE	1.7E-01 ca*	ug/l	0.44	1	3	37	8%	5.8E+00	5.8E-06
PERCHLORATE	3.6E+00 ca/nc	ug/l	1.2	3.8	9	11	82%	1.0E+00	1.0E-06
Total Cancer Risk									2.1E+00

ug/L = micrograms per liter

mg/L = milligrams per liter

ng/L = nanograms per liter

PRG = Preliminary Remediation Goals

Table B-6
Screening Calculation of Noncancer Hazards from Maximum Detected Concentrations in Groundwater at Phase 1A Wells
2004-2005

Parameter	EPA Region IX Tap Water PRG (ug/L)	Units	Minimum	Maximum	Count	Total Count	Frequency	Ratio Conc/PRG
PERCHLORATE	3.6E+00 ca/nc	ug/l	1.2	3.8	9	11	82%	1.0E+00
1,1,1-TRICHLOROETHANE	3.2E+03 nc	ug/l	0.055	12000	27	37	73%	3.8E+00
1,1-DICHLOROETHANE	8.1E+02 nc	ug/l	0.3	150	21	37	57%	1.8E-01
1,1-DICHLOROETHENE	3.4E+02 nc	ug/l	0.56	2200	35	37	95%	6.5E+00
1,2,4-TRIMETHYLBENZENE	1.2E+01 nc	ug/l	0.8	52	3	25	12%	4.2E+00
1,2-DICHLOROBENZENE	3.7E+02 nc	ug/l	3.8	39	6	37	16%	1.1E-01
CIS-1,2-DICHLOROETHENE	6.1E+01 nc	ug/l	0.21	25	12	37	32%	4.1E-01
TRANS-1,2-DICHLOROETHENE	1.2E+02 nc	ug/l	0.79	130	13	37	35%	1.1E+00
1,3,5-TRIMETHYLBENZENE	1.2E+01 nc	ug/l	13	13	1	25	4%	1.1E+00
1,3-DICHLOROBENZENE	1.8E+01 nc	ug/l	0.48	1.4	6	37	16%	7.7E-03
ACETONE	5.5E+03 nc	ug/l	4.9	11000	14	37	38%	2.0E+00
ANTIMONY	1.5E+01 nc	ug/l	0.18	1.9	7	11	64%	1.3E-01
BARIUM	2.6E+03 nc	ug/l	10	73	11	11	100%	2.9E-02
BROMOMETHANE	8.7E+00 nc	ug/l	0.062	180	3	37	8%	2.1E+01
CADMIUM	1.8E+01 nc	ug/l	0.07	0.09	3	11	27%	4.9E-03
CAPROLACTAM	1.8E+04 nc	ug/l	4.2	28	3	11	27%	1.5E-03
CARBON DISULFIDE	1.0E+03 nc	ug/l	0.28	240	4	13	31%	2.3E-01
CHLOROBENZENE	1.1E+02 nc	ug/l	1.9	500	10	37	27%	4.7E+00
CHLOROMETHANE	1.6E+02 nc	ug/l	0.4	2.6	3	37	8%	1.6E-02
CHROMIUM	5.5E+04 nc	ug/l	0.28	5.1	6	11	55%	9.3E-05
CHROMIUM (VI)	1.1E+02 nc	ug/l	2.1	4.2	6	12	50%	3.8E-02
COBALT	7.3E+02 nc	ug/l	0.12	2.7	10	11	91%	3.7E-03
COPPER	1.5E+03 nc	ug/l	0.41	1	9	11	82%	6.8E-04
CYANIDE, TOTAL	7.3E+02 nc	ug/l	2	3.4	2	11	18%	4.7E-03
CYCLOHEXANE	1.0E+04 nc	ug/l	1	1	1	13	8%	9.7E-05
DICHLORODIFLUOROMETHANE	3.9E+02 nc	ug/l	0.5	1.2	4	37	11%	3.0E-03
DIMETHYL PHTHALATE	3.6E+05 nc	ug/l	0.68	0.68	1	11	9%	1.9E-06
ETHYLBENZENE	1.3E+03 nc	ug/l	3.1	41	7	37	19%	3.1E-02
1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE	5.9E+04 nc	ug/l	0.14	2800	33	37	89%	4.7E-02
IRON	1.1E+04 nc	ug/l	37	3350	7	11	64%	3.1E-01
MANGANESE	8.8E+02 nc	ug/l	0.53	4010	11	11	100%	4.6E+00
MERCURY	1.1E+01 nc	ug/l	0.02	0.19	4	11	36%	1.7E-02
METHYL ACETATE	6.1E+03 nc	ug/l	1300	1300	1	12	8%	2.1E-01
NICKEL	7.3E+02 nc	ug/l	1.2	13	11	11	100%	1.8E-02
NITRATE (AS N)	1.0E+04 nc	mg/L	0.17	14	11	11	100%	1.4E+00
NITRITE (AS N)	1.0E+03 nc	mg/L	0.06	0.57	9	11	82%	5.7E-01
N-PROPYLBENZENE	2.4E+02 nc	ug/l	0.42	5.7	6	25	24%	2.3E-02
2-CHLOROTOLUENE	1.2E+02 nc	ug/l	0.28	0.6	4	25	16%	4.9E-03
PHENOL	1.1E+04 nc	ug/l	8.5	20	2	11	18%	1.8E-03
SEC-BUTYLBENZENE	2.4E+02 nc	ug/l	0.26	0.39	3	25	12%	1.6E-03
SELENIUM	1.8E+02 nc	ug/l	1	227	11	11	100%	1.2E+00
TOLUENE	7.2E+02 nc	ug/l	1.1	1300	17	37	46%	1.8E+00
TRICHLOROFLUOROMETHANE	1.3E+03 nc	ug/l	0.6	950	31	37	84%	7.4E-01
VANADIUM	3.6E+01 nc	ug/l	0.35	4.9	9	11	82%	1.3E-01
M,P-XYLENES	2.1E+02 nc	ug/l	0.3	130	7	25	28%	6.3E-01
O-XYLENE	2.1E+02 nc	ug/l	0.55	81	9	25	36%	3.9E-01
TOTAL XYLENES	2.1E+02 nc	ug/l	0.055	75	2	12	17%	3.6E-01
ZINC	1.1E+04 nc	ug/l	1.6	15	11	11	100%	1.4E-03
Total Noncancer Hazard								59

ug/L = micrograms per liter
PRG = Preliminary Remediation Goals

Table B-7
List of Detected Chemicals Without Preliminary Remediation Goals
2004-2005

Parameter	Units	Minimum	Maximum	Count	Total Count	Frequency
2-BUTANONE	ug/l	1.4	770	3	18	17%
2-METHYLNAPHTHALENE	ug/l	0.3	0.3	1	11	9%
ACETOPHENONE	ug/l	2.2	6.9	2	11	18%
AMMONIA NITROGEN (AS N)	mg/L	0.23	0.29	2	11	18%
BICARBONATE ALKALINITY (AS CaCO3)	mg/L	200	570	11	11	100%
BOD 5 DAY (BIOCHEMICAL OXYGEN DEMAND)	mg/L	2	77	11	11	100%
BROMIDE	mg/L	0.14	70	11	11	100%
CALCIUM	ug/l	49500	285999	11	11	100%
CHEMICAL OXYGEN DEMAND	mg/L	3.8	301	9	11	82%
CHLORIDE	mg/L	40	370	11	11	100%
FLUORIDE	mg/L	0.16	0.47	11	11	100%
ISOPROPYL ALCOHOL (ISOPROPANOL)	ug/l	140	140	1	1	100%
ISOPROPYLBENZENE	ug/l	1.5	6.7	6	37	16%
LEAD	ug/l	0.02	0.31	8	11	73%
MAGNESIUM	ug/l	40100	99999	11	11	100%
PHENANTHRENE	ug/l	0.069	0.069	1	11	9%
P-ISOPROPYLTOLUENE	ug/l	0.29	0.86	6	25	24%
POTASSIUM	ug/l	1860	5280	6	11	55%
SODIUM	ug/l	68600	125001	11	11	100%
SULFATE	mg/L	95	430	11	11	100%
TENTATIVELY IDENTIFIED COMPOUND	ug/l	1.1	1.1	1	6	17%
TOTAL ALKALINITY (AS CaCO3)	mg/L	200	570	11	11	100%
TOTAL DISSOLVED SOLIDS	mg/L	630	1500	11	11	100%
TOTAL INORGANIC CARBON	ug/l	1.1	1.1	1	1	100%
TOTAL KJELDAHL NITROGEN (ORGANIC NITRO)	mg/L	0.22	1	7	11	64%
TOTAL ORGANIC CARBON	mg/L	5	74	12	12	100%
TOTAL PHOSPHORUS	mg/L	0.32	0.32	1	11	9%

ug/L = micrograms per liter

mg/L = milligrams per liter

PRG = Preliminary Remediation Goals

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Appendix
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Appendix C

Appendix C

Details of Cost Estimates

Alternative 1 - Conceptual Capital Cost Estimate
On-Site Groundwater Extraction/Treatment/Surface Water Discharge

Assumptions: Engineer's Estimate based upon conceptual design

Expect actual cost to be within a range of plus 50% to minus 30%

The treatment train assumed here will be confirmed by treatability testing and may be changed.

Power supplied from power lines along SE boundary of site

Costs do not include closure costs such as well abandonment and decommissioning of below grade piping

Direct Costs	Subcomponent	Unit Cost	Units	Number of Units	Current Costs
Well Installation					
	On-Site Groundwater Extraction Wells				
	Mobilization/Demobilization	\$10,000	Each	1	\$10,000
	Vertical Extraction Wells (100 ft, 4-inch PVC, with logging, cutting disposal, and development)	\$68,000	Each	14	\$952,000
	Wellhead and traffic-rated vault	\$5,000	Each	14	\$70,000
	Submersible pump, 1/3 HP with controls (0.3 - 7 gpm)	\$4,000	Each	14	\$56,000
	Subtotal				\$1,088,000
Conveyance Piping and Conduits					
	Mobilization/Demobilization	\$10,000	Each	1	\$10,000
	Trench, backfill and re-surface from extraction wells to treatment system enclosure (trench 3' deep x 24" wide 2-inch HDPE pipe)	\$40	LF	900	\$36,000
	Signal Conduit for extraction pumps	\$2	LF	900	\$1,800
	Trench, backfill, re-surface, and piping from treatment enclosure to surface discharge	\$40	LF	400	\$16,000
	Transport/Dispose Trench Soil as Non-Hazardous (assumes a fluff factor of 1.2 and an average wet density of 1.5 tons/CY 100% of total volume is assumed to be non-hazardous)	\$150	CY	347	\$52,000
	Subtotal				\$115,800
Site Work and Demolition					
	Mobilization/Demobilization	\$10,000	Each	1	\$10,000
	Minimal pavement obstructions	\$10,000	LS	1	\$10,000
	Site grading	\$10,000	LS	1	\$10,000
	Landscaping, lighting, repaving	\$100,000	LS	1	\$100,000
	Equipment pads	\$50,000	LS	1	\$50,000
	Subtotal				\$180,000
Groundwater Treatment Equipment					
	Mobilization/Demobilization	\$10,000	Each	1	\$10,000
	Advanced oxidation process (AOP) system (10 gpm capacity)	\$175,000	LS	1	\$175,000
	Liquid phase carbon (two 250-pound units)	\$1,500	each	2	\$3,000
	Initial carbon supply (500 pounds)	\$1.50	lb	500	\$750
	10,000 gal equalization tank	\$25,000	LS	1	\$25,000
	Pump to transfer between treatment enclosure and discharge point	\$7,500	LS	1	\$7,500
	Enclosure for treatment equipment (10 ft x 20 ft)	\$150	SF	200	\$30,000
	Installation of equipment in enclosure	\$50,000	LS	1	\$50,000
	Subtotal				\$301,250
Electrical Power Distribution					
	Electrical Service	\$15,000	LS	1	\$15,000
	Power distribution to wells	\$5,000	well	14	\$70,000
	Power distribution to process equipment	\$8,000	LS	1	\$8,000
	Instrumentation and Controls and Programming	\$50,000	LS	1	\$50,000
	Subtotal				\$143,000
Total Direct Costs					\$1,829,000
Construction Costs (% of Direct Capital Costs)					
	Construction Management (10%)	10%			\$182,900
	Contractor Overhead and Profit (15%)	15%			\$274,350
	Contingency Allowance (25%)	25%			\$457,250
	Legal Fees (5%)	5%			\$91,450
	Regulatory License/Permits (5%)	5%			\$91,450
	Sales Tax (8.25%)	8.25%			\$150,893
Engineering	(15% of Direct costs plus Construction Costs)	15%			\$461,594
Total Indirect Capital Costs					\$1,710,000
TOTAL CAPITAL COSTS					\$3,539,000

Alternative 1 - Conceptual Annual Cost Estimate
On-Site Groundwater Extraction/Treatment/Surface Water Discharge

Direct Annual Costs	Subcomponent	Unit Cost	Units	Number of Units	Cost
Groundwater Extraction and Treatment					
	Treatment System O&M Labor (25% of full-time operator costs)	\$160,000	fraction	0.25	\$40,000
	Treatment System O&M (Includes electricity)	\$25,000	LS	1	\$25,000
	Liquid Phase Carbon Disposal (two changeouts/year = 1,000 lbs/year)	\$2.00	lb	1000	\$2,000
	Liquid Phase Carbon Replacement (1,000 pounds/year)	\$1.50	lb	1000	\$1,500
	Costs for discharge to storm drain	\$15,000	LS	1	\$15,000
	Subtotal				\$83,500
Performance Monitoring Analytical Costs - (Quarterly)					
	GW Extraction Well Streams (collect 1 sample per extraction well plus QA samples analyzed for VOCs, SVOCs, and metals)	\$1,000	Each	70	\$70,000
	Treatment system monitoring (collect influent and effluent samples and QA/QC samples analyzed for VOCs, SVOCs, metals)	\$1,000	Each	40	\$40,000
	Subtotal				\$110,000
Performance Monitoring Sampling/Reporting Costs - (Quarterly)					
		\$10,000	Each	4	\$40,000
	Supervision and Reporting	\$40,000	Each	1	\$40,000
Total Annual Costs					\$273,500
Indirect Annual Costs (% of Direct Capital Costs)					
	Maintenance Reserve and Contingency Costs (20% of annual Costs)				\$54,700
Total Indirect Annual Costs					\$54,700
TOTAL ANNUAL COSTS					\$329,000
TOTAL PROJECT O&M COSTS					
	Assumed Project Life	30	Years		
	Discount rate	7.000%			
	Total Present Worth O&M Costs				\$4,083,000
TOTAL PROJECT COSTS (CAPITAL AND O&M)					
Total Project Cost Summary					
	Capital Costs				\$3,539,000
	O&M Costs				\$4,083,000
Total Present Worth Project Costs, Excluding Closure					\$7,622,000

Alternative 2 - Conceptual Capital Cost Estimate

Source Area Hydraulic Containment/Groundwater Treatment/Surface Water Discharge

Assumptions: Engineer's Estimate based upon 30% conceptual design

Expect actual cost to be within a range of plus 50% to minus 30%

The treatment train assumed here will be confirmed by treatability testing and may be changed.

Power supplied from power lines along SE boundary of site

Costs do not include closure costs such as well abandonment and decommissioning of piping.

Direct Costs	Subcomponent	Unit Cost	Units	Number of Units	Current Costs
Well Installation					
	Hydraulic Containment Extraction Wells				
	Mobilization/Demobilization	\$10,000	Each	2	\$20,000
	Hydraulic Containment Wells (100 ft, 4-inch PVC, with logging, cutting disposal and development)	\$68,000	Each	5	\$340,000
	Wellhead and traffic-rated vault	\$5,000	Each	5	\$25,000
	Submersible pump, 1/3 HP with controls (0.3 - 7 gpm)	\$4,000	Each	5	\$20,000
	Monitoring Wells (including logging, cutting disposal and development)	\$65,000	Each	3	\$195,000
	Subtotal				\$600,000
Conveyance Piping and Conduits					
	Mobilization/Demobilization	\$10,000	Each	1	\$10,000
	Trench, backfill and re-surface from extraction wells to treatment system enclosure (trench 3 ft deep x 2 ft wide 2-inch HDPE pipe)	\$40	LF	900	\$36,000
	Signal Conduit for extraction pumps	\$2	LF	900	\$1,800
	Trench, backfill, re-surface, and piping from treatment enclosure to surface discharge	\$40	LF	400	\$16,000
	Transport/Dispose Trench Soil as Non-Hazardous (assumes a fluff factor of 1.2 and an average wet density of 1.5 tons/CY 100% of total volume is assumed to be non-hazardous)	\$150	CY	347	\$52,000
	Subtotal				\$115,800
Site Work and Demolition -					
	Mobilization/Demobilization	\$10,000	Each	1	\$10,000
	Minimal pavement obstructions	\$10,000	LS	1	\$10,000
	Site grading	\$15,000	LS	1	\$15,000
	Landscaping, lighting, repaving	\$100,000	LS	1	\$100,000
	Equipment pads	\$50,000	LS	1	\$50,000
	Subtotal				\$185,000
Groundwater Treatment Equipment					
	Mobilization/Demobilization	\$10,000	Each	1	\$10,000
	Advanced oxidation process (AOP) system (35 gpm capacity)	\$250,000	LS	1	\$250,000
	Liquid phase carbon (two 500-pound units)	\$6,000	each	2	\$12,000
	Initial carbon supply (1,000 pounds)	\$1.50	lb	1,000	\$1,500
	10,000 gal equalization tank	\$25,000	LS	1	\$25,000
	Pump to transfer between treatment enclosure and discharge point	\$4,000	LS	1	\$4,000
	Enclosure for treatment equipment (15 ft x 25 ft)	\$150	SF	375	\$56,250
	Installation of equipment in enclosure	\$50,000	LS	1	\$50,000
	Subtotal				\$408,750
Electrical Power Distribution					
	Electrical Service	\$15,000	LS	1	\$15,000
	Power distribution to wells	\$5,000	well	5	\$25,000
	Power distribution to process equipment	\$8,000	LS	1	\$8,000
	Instrumentation and Controls and Programming	\$75,000	LS	1	\$75,000
	Subtotal				\$123,000
Total Direct Costs					\$1,433,000
Construction Costs (% of Direct Capital Costs)					
	Construction Management (10%)	10%			\$143,300
	Contractor Overhead and Profit (15%)	15%			\$214,950
	Contingency Allowance (25%)	25%			\$358,250
	Legal Fees (5%)	5%			\$71,650
	Regulatory License/Permits (5%)	5%			\$71,650
	Sales Tax (8.25%)	8.25%			\$118,223
Engineering	(15% of Direct costs plus Construction Costs)	15%			\$361,653
Total Indirect Capital Costs					\$1,340,000
TOTAL CAPITAL COSTS					\$2,773,000

Alternative 2 - Conceptual Annual Cost Estimate
Source Area Hydraulic Containment/Groundwater Treatment/Surface Water Discharge

Direct Annual Costs	Subcomponent	Unit Cost	Units	Number of Units	Cost
Groundwater Extraction and Treatment					
	Treatment System O&M Labor (25% of full-time operator costs)	\$160,000	fraction	0.25	\$40,000
	Treatment System O&M (Includes electricity)	\$30,000	LS	1	\$30,000
	Liquid Phase Carbon Disposal (two change outs/year = 2,000 pounds)	\$1.50	lb	2000	\$3,000
	Liquid Phase Carbon Replacement (2,000 pounds/year)	\$1.50	lb	2000	\$3,000
	Costs for discharge to storm drain	\$20,000	LS	1	\$20,000
	Subtotal				\$96,000
Performance Monitoring Analytical Costs - (Quarterly)					
	GW Extraction Well Streams (collect 1 sample per extraction well plus QA samples analyzed for VOCs, SVOCs, and metals)	\$1,000	Each	30	\$30,000
	Treatment system monitoring (collect influent and effluent samples and QA/QC samples analyzed for VOCs, SVOCs, metals)	\$1,000	Each	40	\$40,000
	Subtotal				\$70,000
Performance Monitoring Reporting Costs - (Quarterly)					
		\$10,000	Each	4	\$40,000
	Supervision and Reporting	\$40,000	Each	1	\$40,000
Total Annual Costs					\$246,000
Indirect Annual Costs (% of Direct Capital Costs)					
	Maintenance Reserve and Contingency Costs (20% of annual Costs)				\$49,200
Total Indirect Annual Costs					\$49,200
TOTAL ANNUAL COSTS					\$296,000
TOTAL PROJECT O&M COSTS					
	Assumed Project Life	30	Years		
	Discount rate	7.000%			
	Total Present Worth O&M Costs				\$3,674,000
TOTAL PROJECT COSTS (CAPITAL AND O&M)					
Total Project Cost Summary					
	Capital Costs				\$2,773,000
	O&M Costs				\$3,674,000
Total Present Worth Project Costs, Excluding Closure					\$6,447,000

Alternative 3 - Conceptual Capital Cost Estimate

Source Area Hydraulic Containment/Groundwater Treatment/Re-Injection for EAB

Assumptions: Engineer's Estimate based upon 30% conceptual design
 Expect actual cost to be within a range of plus 50% to minus 30%
 The treatment train assumed here will be confirmed by treatability testing and may be changed.
 Power supplied from power lines along SE boundary of site
 Costs do not include closure costs such as well abandonment and decommissioning of piping

Direct Costs	Subcomponent	Unit Cost	Units	Number of Units	Current Costs
Well Installation					
	On-Site Groundwater Extraction Wells				
	Mobilization/Demobilization	\$10,000	Each	2	\$20,000
	Vertical Extraction Wells (100 ft, 4-inch PVC, with logging cutting disposal, and development)	\$68,000	Each	5	\$340,000
	Wellhead and traffic-rated vault	\$5,000	Each	5	\$25,000
	Submersible pump, 1/3 HP with controls (0.3 - 7 gpm)	\$4,000	Each	5	\$20,000
	Monitoring Wells (including logging, cutting disposal and development)	\$65,000	Each	3	\$195,000
	Subtotal				\$600,000
Conveyance Piping and Conduits					
	Mobilization/Demobilization	\$10,000	Each	1	\$10,000
	Trench, backfill and re-surface from extraction wells to treatment system enclosure (trench 3 ft deep x 2 ft wide 2-inch HDPE pipe)	\$40	LF	900	\$36,000
	Signal Conduit for extraction pumps	\$2	LF	900	\$1,800
	Trench, backfill, re-surface, and piping from treatment enclosure to re-injection trench	\$40	LF	200	\$8,000
	Transport/Dispose Trench Soil as Non-Hazardous (assumes a fluff factor of 1.2 and an average wet density of 1.5 tons/CY. 100% of total volume is assumed to be non-hazardous)	\$150	CY	293	\$44,000
	Subtotal				\$99,800
Site Work and Demolition -					
	Mobilization/Demobilization	\$10,000	Each	1	\$10,000
	Minimal pavement obstructions	\$10,000	LS	1	\$10,000
	Site grading	\$10,000	LS	1	\$10,000
	Landscaping, lighting, repaving	\$100,000	LS	1	\$100,000
	Equipment pads	\$50,000	LS	1	\$50,000
	Subtotal				\$180,000
Groundwater Treatment Equipment					
	Mobilization/Demobilization	\$10,000	Each	1	\$10,000
	Advanced oxidation process (AOP) system (35 gpm capacity)	\$250,000	LS	1	\$250,000
	Liquid phase carbon (two 500-pound units)	\$6,000	each	2	\$12,000
	Initial carbon supply (1,000 pounds)	\$1.50	lb	1,000	\$1,500
	10,000 gal equalization tank	\$25,000	LS	1	\$25,000
	Pump to transfer between treatment enclosure and re-injection wells	\$4,000	LS	1	\$4,000
	Enclosure for treatment equipment (30 ft x 20 ft)	\$150	SF	600	\$90,000
	Installation of equipment in enclosure	\$50,000	LS	1	\$50,000
	Subtotal				\$442,500
Electrical Power Distribution					
	Electrical Service	\$15,000	LS	1	\$15,000
	Power distribution to wells	\$5,000	well	10	\$50,000
	Power distribution to process equipment	\$8,000	LS	1	\$8,000
	Instrumentation and Controls and Programming	\$100,000	LS	1	\$100,000
	Subtotal				\$173,000
Re-Injection for EAB					
	Bench and pilot scale EAB testing	\$75,000	LS	1	\$75,000
	Mobilization/Demobilization	\$6,000	Each	4	\$24,000
	Excavate re-injection trench (2 ft wide, 150 ft long, 75 ft deep)	\$15	SF	11250	\$168,750
	Transport/Dispose Soil as Non-Hazardous (assumes a fluff factor of 1.2 and an average wet density of 1.5 tons/CY. 50% of total volume is assumed to be non-hazardous)	\$150	CY	500	\$75,000
	Transport/Dispose Soil as RCRA-Hazardous (assumes a fluff factor of 1.2 and an average wet density of 1.5 tons/CY. 50% of total volume is assumed to be RCRA-hazardous)	\$275	CY	500	\$137,500
	Soil VOC analysis to decide disposal	\$250	sample	20	\$5,000
	Place gravel backfill	\$30	CY	600	\$18,000
	Geotextile Cover	\$5	SY	20	\$100
	Re-injection Piping (2 inch HDPE)	\$18	LF	300	\$5,400
	EAB amendment mixing tank	\$25,000	LS	1	\$25,000
	Chemical feed pump and metering equipment	\$10,000	LS	1	\$10,000
					\$543,750
Total Direct Costs					\$2,040,000
Construction Costs (% of Direct Capital Costs)					
	Construction Management (10%)	10%			\$204,000
	Contractor Overhead and Profit (15%)	15%			\$306,000
	Contingency Allowance (25%)	25%			\$510,000
	Legal Fees (5%)	5%			\$102,000
	Regulatory License/Permits (5%)	5%			\$102,000
	Sales Tax (8.25 %)	8.25%			\$168,300
Engineering (15% of Direct costs plus Construction Costs)					\$514,845
Total Indirect Capital Costs					\$1,908,000
TOTAL CAPITAL COSTS					\$3,948,000

Alternative 3 - Conceptual Annual Cost Estimate
Source Area Hydraulic Containment/Groundwater Treatment/Re-Injection for EAB

Direct Annual Costs	Subcomponent	Unit Cost	Units	Number of Units	Cost
Groundwater Extraction and Treatment					
	Treatment System O&M Labor (25% of full-time operator costs)	\$160,000	fraction	0.25	\$40,000
	Treatment System O&M (Includes electricity)	\$40,000	LS	1	\$40,000
	Liquid Phase Carbon Disposal (two change outs/year = 2,000 pounds)	\$2.00	lb	2000	\$4,000
	Liquid Phase Carbon Replacement (2,000 pounds/year)	\$1.50	lb	2000	\$3,000
	Costs for discharge to storm drain	\$15,000	LS	1	\$15,000
	Subtotal				\$102,000
Performance Monitoring Analytical Costs - (Quarterly)					
	GW Extraction Well Streams (collect 1 sample per extraction well plus QA samples analyzed for VOCs, SVOCs, and metals)	\$1,000	Each	30	\$30,000
	Treatment system monitoring (collect influent and effluent samples and QA/QC samples analyzed for VOCs, SVOCs, metals)	\$1,000	Each	40	\$40,000
	Subtotal				\$70,000
	Performance Monitoring Sampling/Reporting Costs - (Quarterly)	\$12,000	Each	4	\$48,000
EAB via Amended Re-Injection					
	Sodium lactate (targeted feed concentration = 3,000 mg/L)	\$1.1	lb	92000	\$101,200
	EAB quarterly monitoring (Collect 7 samples plus QA/QC and analyze for VOCs, sulfate, ferrous iron, dissolved organic carbon)	\$1,000	Each	40	\$40,000
	Subtotal				\$141,200
	Supervision and Reporting	\$40,000	LS	1	\$40,000
Total Annual Costs					\$401,200
Indirect Annual Costs (% of Direct Capital Costs)					
	Maintenance Reserve and Contingency Costs (20% of annual Costs)				\$80,240
Total Indirect Annual Costs					\$80,240
TOTAL ANNUAL COSTS					\$482,000
TOTAL PROJECT O&M COSTS					
	Assumed Project Life	20	Years		
	Discount rate	7.000%			
	Total Present Worth Annual O&M Costs				\$5,107,000
TOTAL PROJECT COSTS (CAPITAL AND O&M)					
Total Project Cost Summary					
	Capital Costs				\$3,948,000
	O&M Costs				\$5,107,000
Total Present Worth Project Costs, Excluding Closure					\$9,055,000

D

Appendix
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Appendix D

Appendix D

Conceptual Design Basis

Alternative 1**Estimation of Drawdown and Capture zone for Recovery Wells**

Objective: Calculate the range of drawdown that may be expected from operation of remediation wells on the Omega site for a 1000 day period at maximum pumping rate and estimate pore volume turnover rates for an on-site mass removal alternative.

Assumptions: Assume that the aquifer has a 20 foot saturated thickness and an estimated hydraulic conductivity of .6 ft/day based on a slug test at well ow1. the maximum acceptable drawdown is assumed to be 10 feet to account for well loss and interference from other wells. More permeable zones may be present in this area. Assume that Jacobs correction to saturated thickness can be used to estimate drawdown.

Method for calculation of drawdown

The Theis method (Theis, 1935) will be used for calculating drawdown, with Jacobs correction (Jacobs, 1946) to account for the decrease in saturated thickness near the well, which will result in additional drawdown. These standard methods are available in any hydrogeology text. All calculations are done using units capability and internal math functions of Mathcad.

define initial parameters using mathcad units

Well Radius $r := 4 \cdot \text{in}$

Storativity $S_w := .1$

Saturated thickness $D := 20 \cdot \text{ft}$

Hydraulic conductivity $k := .6 \cdot \frac{\text{ft}}{\text{day}}$

Transmissivity $T_w := k \cdot D$ $T = 12 \frac{\text{ft}^2}{\text{day}}$

time $\text{time} := 1000 \cdot \text{day}$ assumed time for analysis

discharge $Q := .5 \cdot \frac{\text{gal}}{\text{min}}$ signs set up for positive Q is pumping

Theis well function

$$u := \frac{r^2 \cdot S}{4 \cdot T \cdot \text{time}} \quad *$$

$$W(u) := \int_u^\infty \frac{e^{-u}}{u} du$$

drawdown (positive number) with Jacob's Correction stated as function of k and Q

$$dd(k, Q) := D - \sqrt{D^2 + 2 \cdot \frac{-Q}{4 \cdot \pi \cdot k \cdot D} \cdot W\left(\frac{r^2 \cdot S}{4 \cdot k \cdot D \cdot \text{time}}\right)} \cdot D$$

drawdown as a function of distance for constant k and Q

$$ddr(r, Q, k) := D - \sqrt{D^2 + 2 \cdot \frac{-Q}{4 \cdot \pi \cdot k \cdot D} \cdot W\left(\frac{r^2 \cdot S}{4 \cdot k \cdot D \cdot \text{time}}\right)} \cdot D$$

Check of Jacob method to verify signs are correct

Theis drawdown

$$\frac{Q}{4 \cdot \pi \cdot k \cdot D} \cdot W\left(\frac{r^2 \cdot S}{4 \cdot k \cdot D \cdot \text{time}}\right) = 9.3837 \text{ ft}$$

Jacob drawdown

$$dd(k, Q) = 15.0348 \text{ ft}$$

Now determine the pumping rate that will result in 10 feet of drawdown at the well after 1000 days of pumping

Hydraulic conductivity $k_w := 0.6 \cdot \frac{\text{ft}}{\text{day}}$

initial guess

$$Q_w := 0.01 \cdot \frac{\text{gal}}{\text{min}}$$

use Mathcad solve block

Given

$$dd(k, Q) = 10 \cdot \text{ft}$$

$$\text{flow} := \text{Find}(Q)$$

$$\text{flow} = 0.3996 \frac{\text{gal}}{\text{min}}$$

backcheck the calculation

$$dd(k, \text{flow}) = 10 \text{ ft}$$

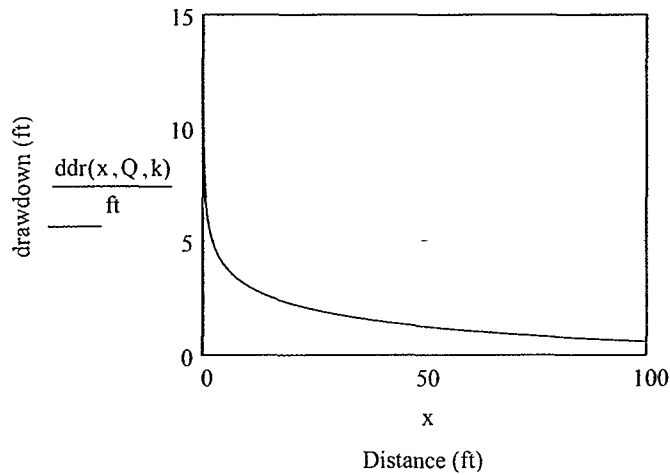
OK

$$Q_w := \text{flow}$$

Calculate distance drawdown

verify units

$$ddr(.25 \cdot \text{ft}, Q, k) = 10.6054 \text{ OK}$$



Assume that the drawdown is near a steady state after 1000 days and then calculate the volume of pore space as a function of distance from the well. This volume can then be used to estimate the time to flush to a distance of 20 feet from the well

Calculate the volume by integration of ddr function from distance zero to 30 feet as a series of concentric shells.

$$Q_w := \text{flow}$$

$$Q = 0.39963109 \frac{\text{gal}}{\text{min}}$$

$$D = 20 \text{ ft}$$

$$\text{volume}(\text{dist}) := \int_0^{\text{dist}} |2 \cdot \pi \cdot S \cdot \text{dist} \cdot (D - \text{ddr}(\text{dist}, Q, k))| \, d\text{dist}$$

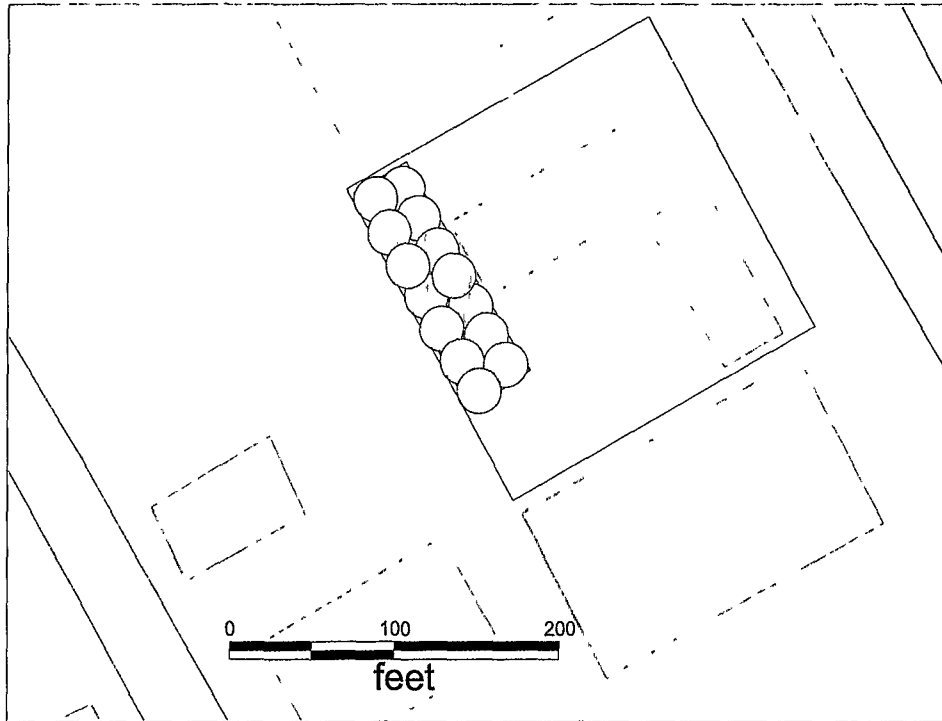
$$\text{volume}(30\text{-ft}) = 4583.4569 \text{ ft}^3$$

$$\frac{\text{volume}(30\text{-ft})}{\text{flow}} = 59.5804 \text{ day}$$

Once equilibrium is reached, it will take $\frac{\text{volume}(30\text{-ft})}{\text{flow}} = 59.5804 \text{ day}$

to turn over the volume within 30 feet of the well after equilibrium is reached. This is based on an assumption that all flow is lateral and no additional water from storage within this 30 foot distance is drained.

The area to be treated for mass removal is shown below, and covers about 5700 ft². This can be covered by 14 mass removal wells to a depth of 100 ft. The actual pumping rate should be reduced further to account for interference from the multiple wells, to an average of .3 gpm per well, or a total production rate of about 4.2 gpm.



Considerable time will be required to reach the steady state, thus total volumes are considered. Calculate the total volume of water in the pore space, including dead pore space, based on the following:

$$\text{total_porosity} := .35$$

$$\text{area} := 5700 \cdot \text{ft}^2 \quad D = 20 \text{ ft}$$

$$\text{volume_water} := \text{area} \cdot D \cdot \text{total_porosity}$$

$$\text{volume_water} = 39900 \text{ ft}^3$$

Length of time to turn over one pore volume

$$\text{flow} = 0.3996 \text{ gpm}$$

$$\text{pore_time} := \frac{\text{volume_water}}{\text{flow}}$$

$$\text{pore_time} = 518.6601 \text{ day}$$

effective porosity is estimated at .1, so the turnover time for active pore space would be:

$$\text{effective_porosity} := .1$$

$$\text{volume_active_water} := \text{area} \cdot D \cdot \text{effective_porosity}$$

$$\text{pore_active_time} := \frac{\text{volume_active_water}}{\text{flow}}$$

$$\text{pore_active_time} = 148.1886 \text{ day}$$

Concentrations will decrease with each pore volume that is pumped

Alternative 2

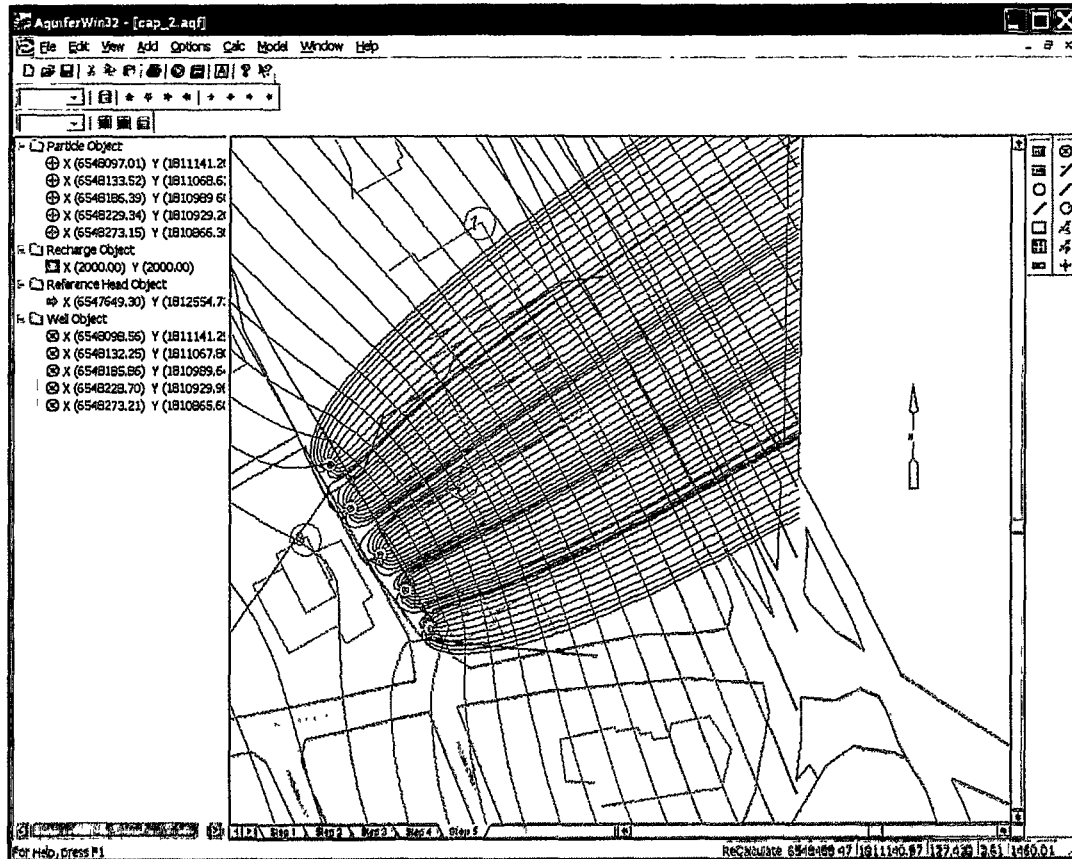
Capture of Upper Aquifer Plume at Putnam Street

Capture zone evaluations were conducted using a simple analytical model to assess flow pathways. This analytical model evaluates the drawdown at individual wells using the Neuman (1972) method and superimposes the cumulative drawdown from multiple wells on a planar regional hydraulic gradient in order to assess groundwater flow pathways. A commercial software package that implements this methodology (AquiferWin32) was used for calculations and to prepare groundwater flow path displays. The calculations were extended to near steady-state conditions, so the selection of storage coefficient does not impact the calculation. The hydraulic characteristics used for the simulation were:

- Hydraulic Conductivity 66 ft/day
- Saturated thickness 12 ft
- Transmissivity 800 ft/day
- Hydraulic gradient 0.008 ft/ft

This methodology and the noted parameters were used in evaluating both alternative 2 and 3.

This simple analytical model was used to assess the potential for capture of the currently defined groundwater plume. This analysis used the hydraulic conductivity, hydraulic gradient and saturated thickness observed during the test at OW-8, as noted above, and assumes that these characteristics extend throughout the area extending upgradient from Putnam Street to the Omega site boundary. The criteria for the area to be contained was based on the occurrence of the defined sand zone observed along Putnam. This target containment zone was used to define locations of wells in the simple model. A total of 5 wells pumping a total of about 28 gpm is required to maintain the full capture zone shown on the following figure.

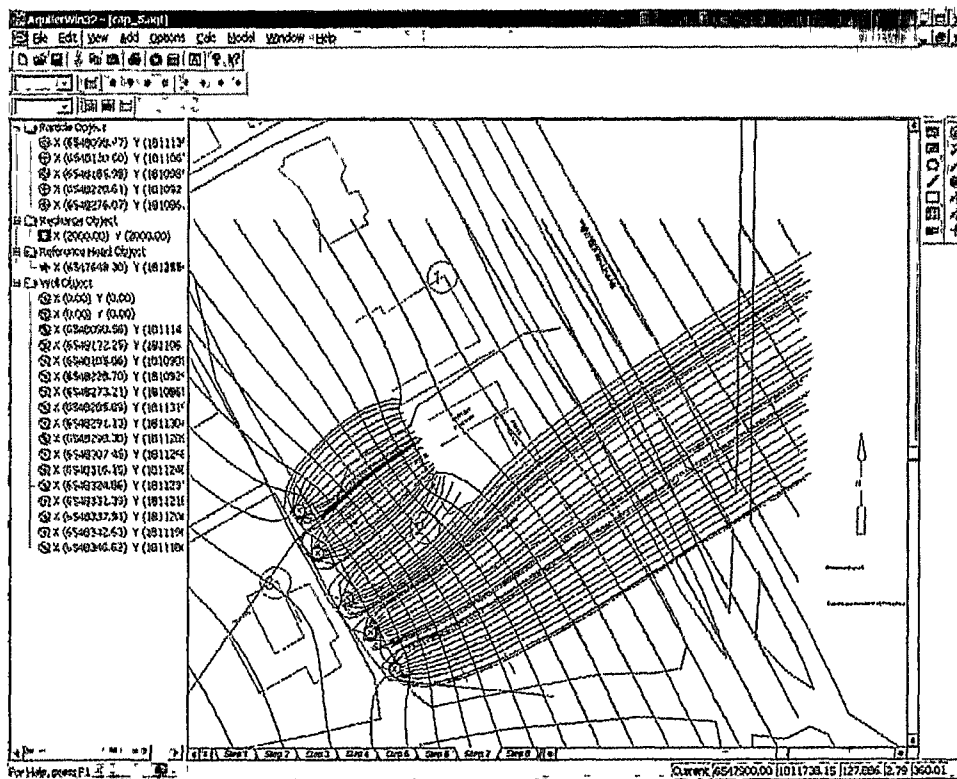


Since the upper aquifer is not a uniform and infinite aquifer, these pumping rates will overestimate the quantity of water that must be pumped in order to maintain capture. The sand lenses are observed to thin toward the site, which will further limit the amount of water that will be required to maintain capture. These estimates are likely an upper limit of the discharge necessary to maintain capture.

Alternative 3

Capture of Upper Aquifer plume at Putnam Street with Re-injection for EAB

The simple analytical model was modified to assess the potential for capture of the currently defined groundwater plume, combined with reinjection of half of the pumped water within the potential source area. This analysis used the hydraulic conductivity, hydraulic gradient and saturated thickness observed during the test at OW-8 and assumes that these properties extend throughout the area extending upgradient from Putnam Street to the Omega site boundary. The criteria for the area to be contained was based on the occurrence of the defined sand zone observed along Putnam. The injection area for EAB enhanced fluids was selected based on the occurrence of elevated soil or soil gas along the eastern property boundary of the Omega site. This target containment zone was used to define locations of wells in the simple model. A total of 5 wells pumping a total of about 28 gpm is required to maintain the full capture zone shown on the following figure. An injection trench infiltrating 12.5 gpm over a 100 foot distance was simulated. All of the injected water will be captured by the containment system at Putnam Street for this scenario, as would additional areas to the south.



Since the upper aquifer is not a uniform and infinite aquifer, these pumping rates will overestimate the quantity of water that must be pumped in order to maintain capture. The sand lenses are observed to thin toward the site, which will further limit the amount of water that will be required to maintain capture. The ability to infiltrate 12.5 gpm will depend on the presence of sufficient permeable intervals to accept this quantity of water.

E

Appendix
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Appendix E

Appendix E

Description of EAB Technology

Appendix E – Description of EAB Technology

In order to discuss biological degradation mechanisms, it is first important to understand the process through which microorganisms produce energy to drive their cellular activities, including growth and maintenance. Microorganisms obtain energy through the mediation of oxidation-reduction, or redox, reactions involving the transfer of electrons from donor compounds to acceptor compounds. The result is the oxidation of an electron donor and reduction of an electron acceptor. For thermodynamic (energetic) reasons, microorganisms preferentially use those electron acceptors that provide the greatest amount of free energy during respiration (Bouwer 1994).

Terminal Electron Acceptor Processes

Typical electron donors in aquifers are naturally occurring organic (carbon-containing) compounds such as humic acids or contaminants such as petroleum hydrocarbons or domestic sewage. Certain inorganic compounds can also serve as electron donors: under aerobic conditions ammonium, nitrite, ferrous iron, and sulfide ions can donate electrons and under anaerobic conditions hydrogen is an important electron donor. The latter is especially important to the biodegradation of chlorinated VOCs.

A relatively small number of compounds can serve as electron acceptors. As noted above, electron acceptors are used in a sequence according to the amount of energy provided to the cell. The order in which common electron acceptors are used is: oxygen, nitrate, ferric iron, sulfate, and finally carbon dioxide (methanogenesis). It should be noted that this is based on thermodynamic considerations only and that the kinetics of a given redox reaction can also be important (Zehnder and Stumm, 1988). The dominant microbial community in a ground water system is largely dependent upon the distribution of electron acceptors. Where oxygen is plentiful, aerobic bacteria will predominate; where oxygen is depleted, but nitrate is plentiful, nitrate-reducing bacteria will predominate; and so on. The importance of electron acceptor utilization patterns to biological communities in ground water has led to the convention of discussing redox conditions in terms of the dominant "terminal electron acceptor process," or TEAP. The predominant TEAP is often inferred based on electron acceptor and reduced product concentrations, and provides a useful indicator of the overall redox conditions.

As each of the inorganic electron acceptors are used in turn, the local environment becomes more reducing, as evidenced by a lower redox potential. The progression of TEAPs and the resultant redox conditions are illustrated in the typical hydrocarbon contamination plume. In the core of the plume, high electron donor concentrations (hydrocarbons in this case) result in utilization of many of the electron acceptors,

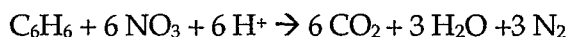
often resulting in methanogenesis and low redox potential. Moving downgradient from the core, less electron donor is available and zones of sulfate reduction and iron reduction are typically encountered. In the fringe of the plume, conditions might be aerobic due to the lack of sufficient electron donor to deplete all of the oxygen in groundwater, and a high redox potential will be measured. Thus, microbial activity has a strong impact on the redox potential of a site.

The oxidation of many electron donors for a given TEAP can be described by stoichiometric equations. In the following equations, the chemical structure for benzene (C₆H₆) is used as a representative electron donor, and microbial growth is neglected for simplicity. In order of most oxidizing to most reducing conditions, the equations for the biodegradation of benzene under various TEAPs are:

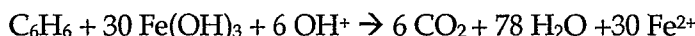
Aerobic Respiration (electron acceptor: oxygen)



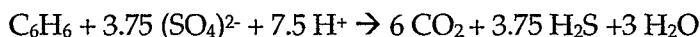
Denitrification (electron acceptor: nitrate)



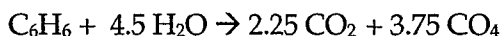
Iron (III) Reduction (electron acceptor: ferric iron)



Sulfate Reduction (electron acceptor: sulfate)



Methanogenesis (electron acceptor: carbon dioxide)



Different microbial populations mediate each of the above TEAPs, and are generally referred to by the type of energy metabolism they use (e.g., denitrifiers, methanogens, etc.). Another important group of bacteria is the fermenters, which use organic compounds as both electron acceptors and donors. In the process, they produce molecular hydrogen that is used by other anaerobes (e.g., sulfate reducers and methanogens) as an electron donor. This reaction is important in the biotransformation of chlorinated solvents because hydrogen is used as the electron donor in the dechlorination process of most chlorinated VOC compounds.

Understanding the basic means by which microorganisms affect groundwater redox condition is critical to analysis of biodegradation mechanisms. Investigations conducted under both field and laboratory conditions indicate that chlorinated solvents can be biotransformed by various pathways under different redox

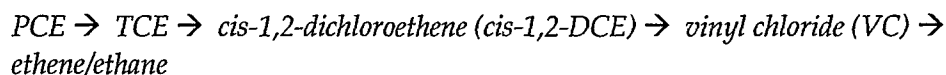
environments. The degradation pathways that occur at a given site are primarily a function of the redox conditions.

Chlorinated Solvent Biodegradation Pathways

The major processes by which chlorinated VOC compounds biodegrade are anaerobic reductive dechlorination, aerobic co-metabolism and direct oxidation. Anaerobic reductive dechlorination involves the replacement of chlorine atoms in the VOC molecule with a hydrogen atom. This is the most prevalent biological reaction and it occurs naturally in many anaerobic environments. An electron donor, usually molecular hydrogen, is necessary for the reduction to occur. Aerobic co-metabolism involves the fortuitous degradation of the VOC compound by enzymes generated for the metabolism of other compounds, e.g., toluene, phenol, and methane. The microorganism gains no energy from the reaction and may be harmed. This reaction is generally very slow in the environment where it occurs, but can be important in some natural environments, and has been engineered in the field. Direct oxidation of some of the less chlorinated VOCs occurs in many special anaerobic or aerobic environments. For ease of discussion, potential degradation pathways are discussed separately for several classes of chlorinated VOCs. The focus herein is primarily on reductive dechlorination and potentially associated reactions that occur under anaerobic conditions. Aerobic co-metabolism is not discussed because of its limited applicability at anaerobic sites and in highly contaminated areas.

Chlorinated Ethenes

The most significant pathway in the environment for biodegradation of chlorinated solvents is anaerobic reductive dechlorination. Reductive dechlorination involves the growth of microorganisms on an organic compound (i.e., electron donor) coupled with the utilization of chlorinated solvents as the electron acceptor instead of naturally occurring inorganic electron acceptors such as iron, sulfate, or carbon dioxide. As a result, chlorinated solvents are biotransformed through a microbiologically-mediated, sequential dechlorination process. The following reaction sequence depicts the reductive dechlorination of TCE to non-toxic ethene and ethane (Freedman and Gossett, 1989; DeBruin et al., 1992):



The above sequence terminates at ethene and ethane (i.e., non-toxic products) under anaerobic conditions; however, the extent of the reaction is determined both by redox conditions and microbiology, as discussed in the Biostimulation and Bioaugmentation section below. Ethene and ethane are readily biodegraded under aerobic conditions to carbon dioxide and water.

While the production of VC needs to be monitored in this pathway, its long-term accumulation is relatively uncommon because of the multiple pathways leading to its degradation. In addition to reductive dechlorination, VC is also known to biodegrade

through oxidation under iron reducing conditions (anaerobic) to carbon dioxide, when ferric iron is biologically available (Bradley and Chapelle, 1997). VC reaction rates were approximately four times faster under Fe(III) reducing conditions compared to methanogenic conditions (Bradley 1997). Although the biodegradation of chlorinated solvents primarily occurs under anaerobic conditions, recent research indicates that VC rapidly biodegrades under aerobic conditions to carbon dioxide and water (Bradley and Chapelle, 1998).

Similar to VC, recent evidence suggests that *cis*-1,2-DCE and 1,1-DCE may also biodegrade under aerobic conditions to carbon dioxide and water (Klier, et al., 1999; Bradley and Chapelle, 2000). Coleman et al. (2002) were able to isolate a bacterium that grows on DCE as a sole carbon source; however, it appears that such organisms might not be common. Although this is an important reaction for consideration at any site, more research on this subject is needed to determine site specific factors affecting the process.

In addition to biodegradation of chlorinated ethenes, new studies have shown that abiotic degradation might be important under some conditions. In particular, the reducing conditions created in biologically active systems have the potential to produce reduced minerals that can act as electron donors for abiotic reduction of chlorinated ethenes (Butler and Hayes, 1999; Lee and Batchelor, 2002a; Lee and Batchelor, 2002b; Wilkin 2003; Wilson and Ferry, 2003). Specifically, significant concentrations of ferrous iron and hydrogen sulfide can be present in groundwater under reducing conditions. This can result in precipitation of iron sulfide minerals, which in turn can chemically reduce chlorinated solvents.

Chlorinated Ethanes

TCA transformations may occur biologically under anaerobic conditions, or abiotically under aerobic and anaerobic conditions. TCA transformations and breakdown products are summarized in Figure D-1. Both abiotic and biological reactions are important to the ultimate fate of the chloroethanes.

Under anaerobic conditions, 1,1,1-TCA may be rapidly transformed by biotic processes into 1,1-DCA (DCA), which may be further reduced to chloroethane (CA), though at slower rates, and to ethane at slower rates yet. CA is relatively stable biologically under anaerobic conditions but is transformed to ethanol and chloride by an abiotic hydrolysis reaction (Vogel and McCarty 1987). The same biological reactions occur for 1,1,2-TCA. This pathway is also shown in Figure D-1.

Biological

1,1-DCE → vinyl chloride (VC) → ethene/ethane

TCA → DCA → chloroethane (CA) → ethane

Abiotic

CA → ethanol, chloride

1,1,1-TCA is also readily transformed abiotically to form 1,1-dichloroethene (1,1-DCE) and acetic acid. The formation of acetic acid is favored and the ratio of acetic acid to 1,1-DCE is 5:1 at 40°C (Vogel and McCarty, 1987). 1,1-DCE can undergo reductive dechlorination to form vinyl chloride (VC), the innocuous ethene and, under some conditions, ethane. Acetic acid is readily degraded under anaerobic conditions to carbon dioxide and methane and its role as an effective electron donor in reductive dechlorination reactions is documented. While 1,1,2-TCA is degraded biologically in a manner similar to 1,1,1-TCA (Figure D-1), no abiotic hydrolysis to 1,1-DCE or acetic acid has been shown to occur (Vogel and McCarty, 1987).

Abiotic

1,1,1-TCA → 1,1-dichloroethene (1,1-DCE)

1,1,1-TCA → acetic acid

Site conditions govern which breakdown products are observed. For instance, abiotic transformation of TCA might predominate in areas where little methanogenic activity is occurring with resultant production and presence of abiotically formed DCE and acetic acid. In biologically active methanogenic areas, DCA would be the predominant breakdown product since biotic reaction rates can be substantially higher than abiotic rates (approximately 6 days versus 9 years for 90 percent reduction of TCA). Additionally, CA may not be detected in site groundwater if the abiotic transformation rate is greater than the rate of biological reductive dechlorination of DCA to CA (Vogel and McCarty, 1987). Likewise, VC produced by the dechlorination of DCE may not be detected if oxidation reactions under iron reducing conditions consume VC as quickly as it is produced.

Chlorinated Methanes

Chlorinated methanes are the most complex of the chlorinated solvents discussed because of the number of pathways they can undergo, and the significant differences between degradation of the more chlorinated compounds and the less chlorinated compounds. The primary chlorinated methane of interest here is dichloromethane (DCM), or methylene chloride, so only the reductive dechlorination pathway for carbon tetrachloride (CT) and chloroform (CF), which includes DCM, is discussed here. This pathway, shown below, is analogous to that for the chloroethenes, in which chlorine atoms are sequentially removed and replaced with hydrogen atoms.

CT → CF → DCM → CM → Methane.

While DCM can be present in groundwater as a degradation product of CT, it has been widely used as an industrial solvent and is often found as an original contaminant. However, DCM plumes are generally much smaller than those for other chlorinated solvents because it is readily biodegradable. Multiple degradation

pathways exist for DCM, including reductive dechlorination (described above), but perhaps more importantly including both aerobic and anaerobic pathways that produce formate (Leisinger and Braus-Stromeyer, 1995; Ma 2000), or formate and acetate (Magli et al., 1998), respectively, as shown below.

Aerobic

DCM → formaldehyde → formate

Anaerobic

DCM → formate

DCM → acetate (→ methane)

DCM is readily biodegraded and has been shown to serve as a sole carbon source under aerobic (Rittmann and McCarty, 1980; Klecka 1982)) and methanogenic conditions (Freedman and Gossett, 1991). In addition to production of formate and acetate, Freedman and Gossett (1991) also observed accumulation of hydrogen during DCM degradation. The significance of this is that all of these compounds have been documented to serve as electron donors to facilitate reductive dechlorination of other chlorinated VOCs. This has been observed in the field at several sites (e.g., Fiorenza et al., 1994). Thus, the presence of DCM, like petroleum hydrocarbons, can actually be a benefit for stimulating degradation at sites contaminated with chlorinated ethenes or ethanes.

Biostimulation and Bioaugmentation

Complete reductive dechlorination generally has two requirements. First, redox conditions must be sufficiently reducing that reductive dechlorination of the lesser chlorinated compounds (e.g., DCE, VC, DCA, etc.) is thermodynamically favorable. For example, while PCE and TCE reduction might occur under iron-reducing conditions, reduction of DCE and VC to ethene generally requires at least sulfate reducing conditions, or more preferably methanogenic conditions (Semprini et al., 1995; Sorenson 2000; NAVFAC 2003). When electron donor is limited, conditions will often not be sufficiently reducing to achieve complete dechlorination, causing it to "stall" at DCE. This can be overcome simply through the addition of a compound that acts as an electron donor, often consisting of a fermentable carbon source (Sorenson 2003).

The process of facilitating degradation of contaminants by indigenous microorganisms simply through addition of a limiting substrate or nutrient to the system is referred to as *biostimulation*. Biostimulation has been demonstrated to be a successful technology for complete degradation of chlorinated solvents at field sites since the 1990s (e.g., Sorenson 2000; Song et al., 2002). When the appropriate microorganisms are present at a site to carry out the desired reactions, the primary determining factor for the success of biostimulation is the distribution of electron

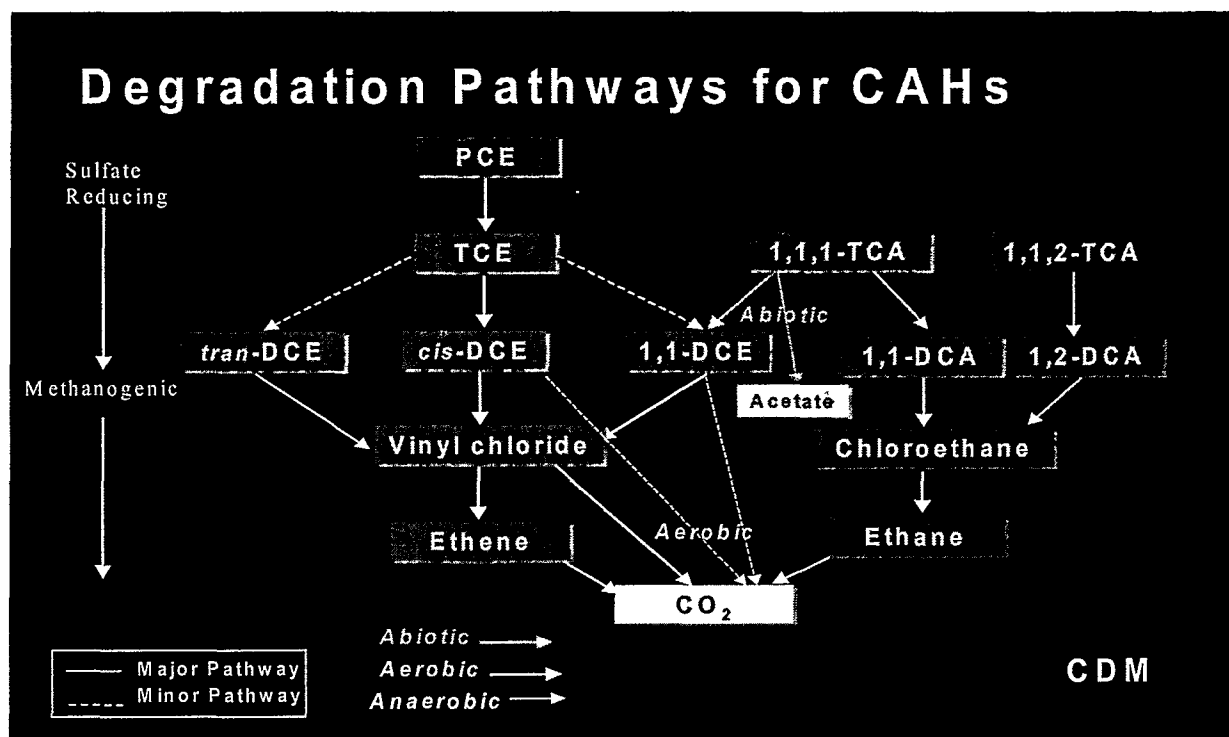
donor in the subsurface. Conditions will not be sufficiently reducing to achieve complete dechlorination in areas that do not receive enough electron donor to deplete all competing electron acceptors. This is a common occurrence in cases where attempts are made to add just enough electron donor to degrade contaminants while limiting methanogenesis (AFCEE 2004). This practice generally arises from concerns about competition for electron donors between dechlorinating bacteria and methanogens at high electron donor levels (Smatlak et al., 1996; Fennell et al., 1997). Recent research suggests, however, that use of hydrogens by methanogens is likely far less significant than use of acetate for methanogenesis at typical groundwater temperatures (Macbeth et al., in press). The need for achieving strongly reducing conditions throughout the treatment area is therefore a much more important for electron donor addition strategies than concerns about competition for hydrogen.

The second requirement for complete reductive dechlorination, as alluded to above, is a biological community capable of carrying out the reaction. It is widely accepted that bacteria capable of anaerobic reductive dechlorination are vital to biological dehalogenation processes in anoxic environments (Smidt et al., 2000). In fact, an increasing body of evidence suggests that complete biological reductive dechlorination of PCE and TCE to ethene requires the presence of a strain of the bacterium *Dehalococcoides* spp. (Cupples et al., 2003; He et al., 2003; Hendrickson et al., 2002). Recent advances in molecular techniques now allow characterization of microbial communities, including identification of dechlorinators, as never before. This has led to the discovery of many organisms capable of dechlorinating various compounds (Holliger et al., 1999). Many of these organisms are capable of reducing PCE and TCE to DCE (Holliger et al., 1999; Drzyzga and Gottschalk, 2002), but only *Dehalococcoides* spp. have been found to be capable of complete dechlorination of PCE and TCE to ethene in a pure culture (Maymo-Gatell et al., 1997; Maymo-Gatell et al., 1999; Maymo-Gatell et al., 2001). A different strain, *Dehalococcoides* strain FL2, has been implicated for complete dechlorination in a mixed culture, but it has not been isolated to date (Löffler et al., 2000). Of particular importance is that a recent study of 24 field sites in North America and Europe found that strains of this organism were present at all 21 sites that exhibited complete dechlorination to ethene, while none were found at the three sites examined where dechlorination stopped at cis-DCE (Hendrickson et al., 2002). This suggests that while *Dehalococcoides* spp. are relatively common and widely distributed their absence at a site might prevent complete dechlorination. It should be noted that detection of the *Dehalococcoides* genus does not necessarily mean that complete dechlorination of PCE or TCE will occur at a site because some strains are not capable of dechlorinating PCE and TCE. For example, strain CBDB1 grows by the dechlorination of chlorinated benzenes and possibly dioxins, but cannot grow by dechlorination of PCE or TCE (Adrian et al., 2000; Bunge et al., 2003).

Bioaugmentation, the in situ addition of an exogenous bacterial culture containing *Dehalococcoides* spp. to site groundwater, is gaining acceptance as a viable strategy particularly for remediation of chlorinated ethenes in groundwater, especially when

these bacteria are not naturally present at a site and reductive dechlorination is found to "stall" at cis-1,2-dichloroethene (cis-DCE). Several laboratory cultures containing *Dehalococcoides* spp., e.g., *Dehalococcoides ethenogenes* have been shown to be capable of complete dechlorination of PCE, TCE, and DCE to ethene (Fennell et al., 2001, Maymo-Gatell et al., 1997; Maymo-Gatell et al., 1999; Richardson et al., 2002). In addition, several studies have demonstrated that bioaugmentation using *Dehalococcoides* spp.-containing mixed cultures can overcome DCE stall and facilitate complete dechlorination at the field pilot scale (Ellis et al., 2000; Major et al., 2002; Lendvay et al., 2003). While these field studies have utilized recirculation systems to transport the added bacteria in the subsurface, passive transport has also been demonstrated recently at the pilot scale (French et al., 2004). Typically, approximately 20 L of an actively dechlorinating exogenous culture is added to one or more wells at a site that is already under reducing conditions. Complete dechlorination often begins within the first month of bioaugmentation. The success of biostimulation and bioaugmentation has resulted in their selection as the most cost-effective remedy at a large number of sites.

Figure E-1





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